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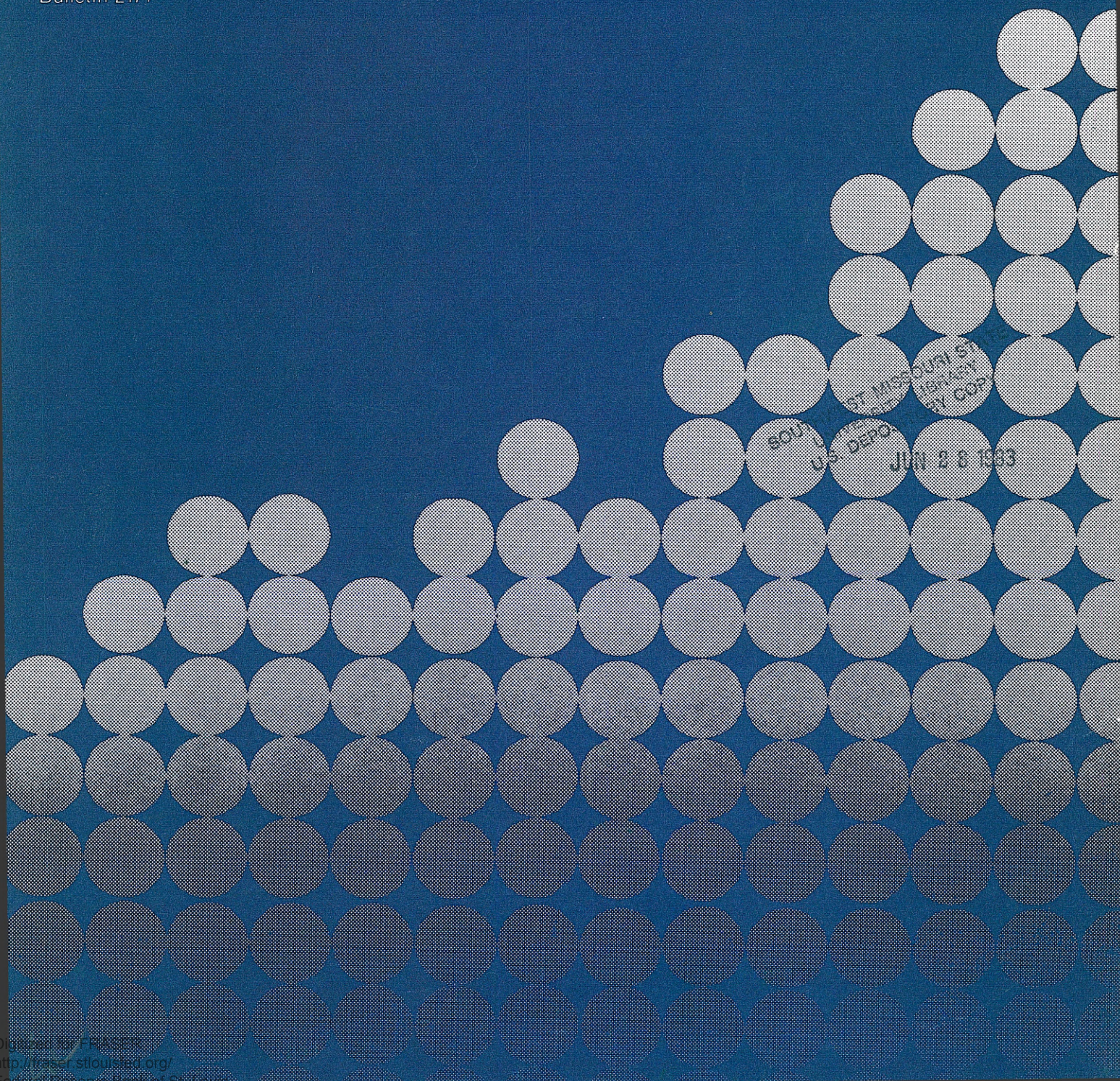
A BLS Reader on Productivity

Reprinted from the Monthly Labor Review and other sources

U.S. Department of Labor
Bureau of Labor Statistics
June 1983

Bulletin 2171



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A BLS Reader on Productivity

Reprinted from the Monthly Labor Review and other sources

U.S. Department of Labor
Raymond J. Donovan, Secretary

Bureau of Labor Statistics
Janet L. Norwood, Commissioner

June 1983

Bulletin 2171

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Preface

This reader presents articles from the *Monthly Labor Review* and other publications, which discuss concepts and measurement of productivity and related variables. They analyze productivity in a number of industries and the factors underlying productivity change over time. They examine productivity measurement and trends in the Federal Government; technological developments and their impact on employment in a variety of industries; and international comparisons of productivity. In addition, the reader contains a number of illustrative statistical tables and charts.

Data for 1982 were not available for many of the statistical series included in the tables at the time the reader went to press. Such data will be furnished to interested parties upon request.

The reader was prepared by the staff of the Office of Productivity and Technology, Bureau of Labor Statistics, U.S. Department of Labor.

JEROME A. MARK
Associate Commissioner for
Productivity and Technology

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Part I. Concepts and Techniques of Productivity Measurement

The first section of the BLS *Reader on Productivity* introduces the basic concepts and ideas of productivity measurement. Productivity refers to the relationship between output and input. Generally speaking, a productivity measure reflects the efficiency with which a given output is produced by the resources employed. This relationship takes a great variety of forms. The two essays included here discuss two types of productivity measures. Each is made up of several groups of measures. One of the two types relates output to a single input, such as labor, capital, or energy. The other relates output to a combination of inputs, such as labor and capital combined. Both types are discussed in this Reader.

Although the productivity measures discussed here relate output to hours of persons engaged in production (hours of employment) or to labor and capital combined, they do not measure the specific contributions of labor, capital, or any other single factor of production. Rather, they reflect the joint effects of many influences, including new technology, capital investment, the level of output, capacity utilization, energy use, and managerial skill, as well as the skills and efforts of the work force.

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Concepts and Measures of Productivity

by Jerome A. Mark*

Despite the wide attention paid to productivity over the years, confusion prevails as to its meaning and measurement. This is understandable because the concept does lend itself to ambiguity and a wide range of productivity measures can and have been developed in response to different analytical uses.

Productivity is loosely interpreted to be the efficiency with which output is produced by the resources utilized. A measure of productivity is generally defined as a ratio relating output (goods and services) to one or more of the inputs (labor, capital, energy, etc.) which were associated with that output. More specifically, it is an expression of the physical or real volume of goods and services related to the physical or real quantities of inputs.

A variety of plausible productivity measures can be developed, the particular form depending on the purpose to be served. For example, output per labor input, the most familiar measure, is useful in understanding changes in employment or labor costs. This measure might be based on man-hours paid or man-hours worked, with different results. A more comprehensive measure of input might be more useful in studying how the economy is using labor and capital combined. Also, there are various ways of adding up diverse products into a measure of output. No one measure is the *right* or *best* measure.

Since the interpretation of these statistics depends on the definitions and data used, an understanding of the productivity concepts used in relation to the purpose to be served is always essential.

CONCEPTS OF PRODUCTIVITY

There are two broad classes into which productivity concepts and in turn measures can be grouped. One includes those measures which relate output of a producing enterprise, industry, or economy to one type of input such as labor, capital, energy, etc.; the other includes those which relate output to a combination of inputs extending to a weighted aggregate of all associate inputs.[1]

Although the former measures relate output to one input, they do not measure the specific contribution of that factor to production. Rather, they express the joint effect of a number of interrelated influences on the use of the factor in the production process—such as changes in technology, substitution of one factor for another, utilization of capacity, layout and flow of material, the skill levels and the efforts of the work force, and managerial and organizational skills.

Whether for an individual establishment, an industry, or the entire economy, the most frequently developed and perhaps most useful productivity measure is an output per unit of labor input measure of what is frequently termed a labor productivity measure. There are several reasons for this. Perhaps the most important is that labor is almost universally required for carrying through all types of production. There is a labor element of costs in almost all endeavors; the degree varies but it is always present. In addition, as a practical matter, it is perhaps the most measurable input. Other factors, such as capital, are much more difficult to quantify.

There are, however, various labor productivity measures, depending on the definition of labor input. A measure may refer to output per person or it may take account of changes in hours of work and be based on total hours. It may cover the hours of the entire labor force including proprietors, unpaid family workers, and employers; or it may be limited to selected groups of workers.

Another set of productivity measures relating output to a single input is output per unit of capital. These measures are particularly useful in understanding movements in unit nonlabor costs by relating the measures to corresponding measures of returns to capital. As in the case of other single factor productivity measures they indicate the changes in the use of capital per unit of output not the contribution of capital alone. The measures

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[1] Even at the level of an individual craftsman where the output-input relationships are limited, these two concepts are present. Productivity can refer to the volume of work the individual is able to accomplish within a given time span—i.e., output per man-hour. It can also refer to the volume of work completed per unit of his time, his tools, and his materials—i.e., an output per total factor input.

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The Meaning and Measurement of Productivity.

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have been limited to reproduction of what has been termed "tangible" capital.

Other single factor measures such as output per energy input or output per material input are relevant for plant and industry study where these inputs are of considerable importance in the production process or represent relatively scarce resources. For example, in the aluminum industry where electrical power is an important element in processing bauxite, output per KWH is very useful as an indication of the efficiency with which electricity is being utilized.

As mentioned earlier, all single factor productivity measures reflect the joint effect of a variety of factors including the substitution of one factor for another. For some purposes, to develop a measure which eliminates the effect of that substitution is useful. This type of measure relates output to a combination of inputs. Thus, a productivity index of output per labor and capital combined elininates the effects of changes in amounts of capital per workers These measures have been termed multifactor or "total factor" or simply "total" productivity measures. For both conceptual and statistical reasons they have generally been limited to labor and "tangible" capital inputs and have not included as inputs activities such as research and education which can be viewed as intangible capital.[2]

Output

For all productivity measures, output is measured in physical or real terms. The concept is one of work done or the amount of product added in the various enterprises, industries, sectors, or economy. It refers not to activity as such but to the results of activity.

In this sense, at the plant level, production and hence productivity measurement differs from work measurement. Work measurement generally refers to the analysis of the stages of activity and the requirements at each of these stages. Productivity refers to the finished product (the result of activity) and its relationship to input.

In the case of a producing unit making one homogeneous commodity, production in physical terms would merely be a count of units produced. For a commodity to be regarded as homogeneous, certain conditions should be fulfilled. The product should be of a specified quality (e.g., carbon steel) and it must conform to precise standards of size, volume, unit, etc. Even though the measure of production in this case is a single count, the way of defining the unit of product can have different implications for productivity measurement. For example, carpeting can be measured in pounds or square yards. A change in the density of the carpeting would affect the weight per yard and, therefore, have a different impact on man-hour requirements depending on whether output is measured by the yard or by the pound.

For the more usual case of a plant or an industry producing many heterogeneous products, the different units must be expressed on some common basis. They can also be combined in terms of their man-hour requirements. The advantage of the latter method for measures of output per man-hour is that the change in the productivity of the entire plant or industry is then a simple arithmetic average of the changes in the productivity of the individual components.

When the components are combined with value or price weights, that is, on the basis of their dollar value, then the output per man-hour measure for the total reflects not only changes in the productivity of the components but shifts in the importance of the components.

Physical quantity data are often not readily available, so deflation of dollar value is used. That is, total value of production is adjusted for change in price by use of a price index. This type of index is usually referred to as constant dollar output or deflated value of output. Such indexes are conceptually equivalent to indexes which use physical quantities combined with price weights.

The contribution of a producing unit lies in the value added, by its own labor and capital, to the materials and services purchased from other producing units—i.e., its net addition. Net output, therefore, is the constant dollar value of production minus the constant dollar value of purchased goods and services. In measuring productivity, the net measure would then be related to the particular input or all associated inputs except the material inputs. Relating a net output measure to a single input, when the various commodities produced and purchased are combined with value or price weights, will result in a single factor productivity measure that reflects not only the changes in productivity of the components and shifts in the importance of these components but also savings in material consumption.

Labor input

For all productivity measures where labor is relevant, labor input is measured in physical terms. The measure can refer either to the total number of individuals engaged in production or to only part of the work force, or it can refer to the man-hours of workers.

It is usually preferable to include the entire employed work force in the labor input measure—blue-collar and

[2] Denison in his work on the sources of economic growth has made estimates of the contributions of intangible factor input such as research, education, organization, etc., to total output. See Edward Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (New York, 1962) and *Why Growth Rates Differ* (Washington, D.C., The Brookings Institution, 1967).

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white-collar workers, corporate officers, and the self-employed. The assessment of manpower needs must take all labor input requirements into account. But of course, there are times when analysis of labor requirements and the analysis of cost components suggests the use of measures which include only a component of the work force.

To analyze the productive capacity of labor and the effects of changes in working hours, or in use for projections of manpower needs, an output per man-hour measure is most relevant. The most suitable unit of measure is man-hours worked. There are some ambiguities or differences of opinion on what to include, for example, standby time, coffee breaks, etc. In general, "hours worked" refers to the time spent at the place of employment, and therefore excludes hours paid for but used on leave for vacation, holiday, illness, accident, etc. In some cases, total hours paid are utilized in the productivity measures because data on hours worked are not available.

In developing a labor input measure, in many cases man-hours are treated as homogeneous and additive. These measures are particularly relevant to problems of estimating total man-hour requirements. But merely adding up the number of hours ignores the qualitative aspect of an hour worked by different individuals. Therefore, a productivity measure which is based on the sum of undifferentiated man-hours will reflect changes in the composition of the work force with different qualitative characteristics.

For some purposes, it may be desirable to develop a productivity measure which takes into account the differences in the "quality" of an hour of labor. That is, an hour of high quality labor is counted as proportionately more than an hour of low quality labor. To do this some methods have to be introduced to differentiate these hours. One way which has been utilized is to combine the man-hours of various employees in terms of pay differentials. The man-hours of higher paid workers are given more weight than lower paid. This assumes that differences in earnings reflect differences in education, experience, skill, and their contribution to output.[3] Another method is to adjust the data to take into account changes in vocational training, length of schooling, or type of education, etc., of the work force, assuming there is a close relationship between qualifications and quality. When adjustments are made for changes in the quality of labor input the resultant productivity measure will not reflect changes in the composition of the work force as a productivity change but rather as a change in factor input.

[3] Except to the extent that regional or similar wage differentials affect average hourly earnings.

Capital input

Capital stock estimates include the constant dollar value of structures, plants, and equipment current available for production. These estimates may also take into account the value of land, inventories, and working capital.

Generally capital stock measures are derived by adjusting the value of existing plant and equipment for new investment and the retirement of old assets. There are different ways of measuring the stock of capital; for example, they may be gross or net. Net stock estimates are derived by depreciating assets (and there are various methods of depreciation). Gross stock estimates are derived by retaining assets at their full value until they are retired from use. Since these are physical measures, the value of capital stock must be adjusted for price changes.

For productivity analysis, however, the flow of capital services rather than the stock is the preferred measure. A capital stock measure does not account for differences in the intensity of use over time. Equipment, for example, may be used for several shifts during a business expansion or may be idle during a contraction. Then, too, a large part of existing capital capacity may be standby and employed only during periods when the economy is operating at very high rates. There is also a loss of efficiency of assets as they grow older. A flow measure reflects differences in usage and efficiency and how they affect varying levels of output, which is the basis of productivity estimation. Ideally flow measures should indicate the amount of capital employed to produce current output.

To derive this capital flow measure, an aggregate of the capital hours used weighted by the rental value of each type of structure and piece of equipment is needed. The data for this measure are often not available in the detail necessary for a capital flow measure.

A commonly used flow of capital service measure is depreciation. However, this is based on accounting principles which often reflect current income tax regulations rather than the actual amount of capital used for current production. Because of the difficulty of estimating a capital flow measure, however, most analyses of capital and production use capital stock estimates.

PROBLEMS OF MEASUREMENT OF PRODUCTIVITY

The measurement of productivity trends involves two fundamental problems which are applicable to both output and input data. First, because of difficulties in obtaining direct quantity measures of output and input, substitute measures or approximations must be used in many cases. Second, since most data are collected for

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purposes other than productivity measurement, definitions already established and procedures for reporting information on production and factor inputs must be used; these may or may not be consistent with concepts appropriate for productivity measurement.

Output

Economy and sector level. The problems of using the gross national product data for productivity measurement involve primarily the inadequacies of the measures of real output for some components and the lack of comparability of coverage between output and labor input measures.

Limitations in measuring output affect the reliability of productivity statistics in some sectors more than others. Since the implications for productivity movements can be offsetting among the sectors, the effect on measures for the overall economy is not as large as it is in each of the sectors.

The three areas where the real product measures as derived from the national accounts are particularly weak for productivity measurement are government, construction, and services (including business and personal services, and finance, insurance, and real estate).

In the absence of market valuation of the services of general government agencies, the practice in national income accounting is to value government output in terms of the wages and salaries of government employees. The deflated, or constant dollar, measure is derived from changes in employment. Such an output measure, when related to a labor input measure, results in no statistical change in productivity. This measure of government output may be increasingly difficult to continue in view of the reported increases in output per man-hour in certain government operations which are subject to measurement. [4] Based on these data the trend of output per man-hour for the national economy would be biased downward. As a consequence, the available measures of productivity are limited to the private economy.

Measuring output in the service activities is difficult because of the absence of a directly quantifiable entity which describes a unit of service. Consequently, various substitute indicators are utilized in the national accounts. These usually involve the use of some "price" index for deflating the value of the service activities or the use of an employment index to develop trends in producers of services.

As in the case of government, the use of the employment movements as an indicator of the change in real output implies a constant labor productivity. This approach is utilized for such activities as security and commodity brokers, [5] insurance agents, and miscellaneous business and repair services.

For the bulk of service activities, however, the deflation approach is used and its validity for the resultant output measure rests on the adequacy of the price indexes. Most of the price indexes used are components of the Consumer Price Index, which in turn have different degrees of reliability. The indexes for medical services, for example, do not adequately take into account changes in the quality of medical services performed.

As mentioned earlier, the real product measure is conceptually a net output measure but in many of the service activities data are not available on the real value of the material inputs. In such cases estimates of real product are made on the basis of changes in the total volume of output. This does not present a serious problem, however, since in most service industries intermediate purchases constitute a relatively small proportion of total value.

The other major activity in the national accounts where the output measure has severe limitations for productivity measurement is the construction industry. The constant dollar output measure is obtained by deflation, but the price index used is really a cost index. For the most part, these are measures of the change in costs of materials and labor weighted in terms of their base period importance. These indexes do not take into account any savings in the utilization of materials or labor, and, as a result, there is an overstatement of price increases. Consequently, there is an understatement of gains in real output and hence productivity.

Productivity indexes based on real product for construction show an average annual decline of 0.2 percent. This is somewhat inconsistent with studies which the Bureau of Labor Statistics has conducted of labor requirements for various specific types of construction during this period. These studies indicate for schools there was approximately a 2¾ percent per year gain over much of this period, for highways a 3-percent increase per year, and for hospitals not much change.

With regard to lack of comparability of coverage between output and labor, perhaps the largest evidence of this occurs in the real estate activity. For national income accounting purposes, an inputed rent for home ownership is added to the output of the real estate industry. There is, however, no corresponding labor in-

[4] Nestor E. Terleckyj "Recent Trends in Output and Input of the Federal Government," in Proceedings of the Business and Economics Section, American Statistical Association, 1964, pp. 76-94.

[5] In view of the rapid spread in recent years of electronic data processing in this industry this measure must be very much understated since the productivity gains undoubtedly were large, John Kendrick has suggested that data on shares of stocks and bonds sold appropriately weighted would be a better measure. See "Production and Productivity in the Service Industries," Victor Fuchs, Educational Studies in Income and Wealth No. 39, National Bureau of Economic Research, 1969.

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put associated with that output. Rough estimates indicate that the removal of this activity from the output account would reduce the productivity trend for the private economy about two-tenths of a percent per year over the last two decades.

Industry level. The effects of certain measurement problems are greater at the individual industry level than at the national level where there is a tendency for errors and biases to offset each other. On the other hand, at the industry level, more flexibility is possible because the output measures are not part of an overall framework (such as the national income and product accounts) which requires certain definitions and measures not necessarily consistent with the desired productivity measures.

Three major problems are encountered in developing measures of output from available data for industry productivity indexes. First, for many industries, the appropriate detailed product data are not available. Second, there is the well known quality change problem which results from the development of new products and the changing specifications of existing products. Third, appropriate weights are often not available for deriving the desired industry measure.

Some of the presently available industry indexes are based on unit man-hour weights; others are based on unit value or price. The use of unit value or price weights is not a serious problem among commodities where labor consts or inputs are a high proportion of price.

Labor input

With regard to labor input measures there are several data gaps in presently available measures. They relate to changes in the composition of labor (the quality), groups of the work force for which data are lacking or incomplete, the relationship of output to the time of research development and other workers whose activities are not directed to current production, and finally, the absence of adequate hours worked data on a comprehensive basis.

1. *Quality.* As mentioned earlier, changes in the composition of labor input are adjusted in some measures by weighting industry man-hours with the average hourly earnings of workers in the industry. Insofar as earnings differentials reflect productivity differences among workers, this measure captures changes in the quality of workers of different industries. However, this approach has severe limitations. Pay differentials between industries reflect many factors unrelated to productivity differences, such as the degree of unionization or regional and geographical differentials. Moreover, the industry hourly earnings differential does not take into account occupational changes which occur within an industry.

Estimates of the effects of shifts among major sectors—farming, manufacturing, mining, etc., show that shifts contributed about 0.3 percent per year of the output per man-hour growth over the last two decades. The shift in composition of the work force within manufacturing between production and nonproduction workers contributed 0.1 percent per year to the rate of increase in private output per man-hour over the last two decades. In recent years this has been reduced considerably to less than 0.05 percentage points.

In view of the limited information on occupational detail, another approach (followed by Denison) to ascertain the impact of shifts and changes in the work force has been to utilize information on changes in age, sex, and education. He estimates, for example, that the increase in education of the work force contributed 0.7 percentage points to the trend rate in output per man-hour from 1950-62. For a longer period, 1929-57, he estimates the effect to be 0.9 percentage points per year. Another estimate of the contribution of education to the growth rate by Schwartzman [6] provides a much lower figure—three-tenths of a percent per year for a roughly comparable period, 1929-63. The magnitude of these differences in this critical area suggests that there is need for further exploration of the interrelationship between education skills, training, earnings, and productivity.

2. *Gaps in coverage.* Payroll data on employment and average weekly hours, which are the primary source of man-hours estimates, do not include the entire economy, but are limited to nonfarm wage and salary workers. These data do not cover farm workers, proprietors, unpaid family workers, and domestics. Estimates for these sectors, for the most part, are taken from the labor force series (based on household surveys) which is not strictly comparable to the payroll series. Employment is a count of persons rather than jobs as in the payroll data, so that appropriate adjustments must be made.

Average hours for supervisory workers in nonmanufacturing industries are not available. The assumption is made that the average workweek for these workers is the same as for the nonsupervisory workers in each industry. Since 85 percent of all employees in nonmanufacturing industries are nonsupervisory workers, however, the effect of this imputation may be minimal.

Sampling procedures also affect the man-hours estimates. One week of each month is used to represent the entire month. If anything unusual, such as an unpaid holiday, strike, or bad weather, occurs during this period, the estimates will reflect these aberrations for the entire

[6] David Schwartzman, "Education and the Quality of Labor, 1929-63," *American Economic Review,* June 1968.

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month. On the other hand, fluctuations in employment between survey periods may not be reflected in the sample estimates. For example, short-term layoffs and plant shutdowns of 1 to 2 weeks between survey periods would not be reflected in the man-hour estimates for the month—leading to an overestimate of man-hours and an underestimate of productivity.

3. *Hours paid versus hours worked.* Because of lack of data, productivity measures for the most part refer to hours paid rather than the more desirable measure of hours worked.

Surveys now are being conducted biannually for the nonfarm economy where information on leave hours and hours worked will soon provide a body of data which will fill some gaps in this area. Estimates of the effects of the difference between hours paid for but not worked on output per man-hour measures developed by the Bureau of Labor Statistics indicate that the effect over the last 15 years has been about 0.1 percent per year for the nonfarm economy.

The effects of course can vary substantially by sector and at the industry level. Within manufacturing, the annual surveys and censuses of manufactures do provide measures of what could be termed plant man-hours, and these are used in many industry productivity measures.

Total factor measures

Total factor productivity measures relate output to the weighted sum of labor and capital and are therefore subject to the limitations of each of these data series. The problems of measuring output and labor input have been discussed. Capital measures, however, are probably the most difficult and complex measures to derive. They contain highly differentiated elements, and to express this differentiated stock in physical terms requires adjusting dollar values of assets for price change.

For the most part, available data for prices of structures are based primarily on cost information. As mentioned earlier, they do not take into account savings in utilization of materials and other inputs. Furthermore, the problems of obtaining representative prices for equipment which is highly differentiated severely affects the adequacy of the price measures used in capital measurement.

In addition, technical advances are often built into capital so that a piece of equipment produced in an earlier period may not be as efficient as one currently produced. In constructing price indexes, some of these technical improvements may be incorporated as quality changes, but adjusting for quality is often difficult. There is some question as to whether improvements in the quality of new capital should be incorporated in the capital stock measures or treated as a productivity increase. Both interpretations have been used in productivity analysis.

Total factor measures as currently presented are not consistent with their treatment of capital and labor. In general, labor refers to actual man-hours whereas capital refers to available stock not taking into account varying levels of utilization.

AVAILABLE MEASURES OF PRODUCTIVITY

Labor productivity

National measures. Each quarter, the BLS prepares and publishes indexes of output per man-hour for the private economy and for the farm, nonfarm, and manufacturing sectors. [7] For these measures, output per man-hour refers to the constant dollar value of goods and services produced in relation to the man-hours of all persons employed (including proprietors and unpaid family workers). Corresponding and comparable indexes of hourly compensation and unit labor costs are also developed.

The output measure for these productivity indexes is real gross national product originating in the private economy or the individual sectors. It comprises the purchase of goods and services by consumers, gross private domestic investment (including the change in business inventors), net foreign investment, and government all deflated separately for changes in prices.

Final goods and services are differentiated from intermediate products in that they are usually not purchased for further fabrication or resale. In addition to purchases in the market, final goods and services also include some items provided but not actually purchased such as food furnished to employees, food produced and consumed on farms, and the rental value of owner occupied homes.

Measures for the farm, nonfarm and manufacturing sectors are derived by subtracting the value of goods and services purchased by the sector from the constant dollar value of products and services leaving the sector. [8]

The labor input measures for these series are based largely on a monthly survey of establishment payroll records. Since this survey does not cover total employment in the private economy and because there are gaps in the hours information, it is necessary to use some supplementary data to derive man-hours estimates for all persons engaged in producing the output of the private

[7] *Productivity, Wages and Prices,* quarterly release issued by the Bureau of Labor Statistics, U.S. Department of Labor.

[8] This actual measures are developed according to a variety of approaches because of data limitations. However, all are attempts to approximate this concept.

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economy. Various sources are utilized and data from them are adjusted for consistency with the establishment man-hours.

The establishment man-hours are based on an hours paid rather than an hours worked concept. That is, the estimates include paid holidays, vacations, sick leave and other time off paid for by the employer in addition to actual hours worked.

Another set of labor productivity indexes is developed based on man-hours obtained from a monthly survey of the noninstitutional civilian population. This survey of households provides information on the labor force, employment, unemployment as well as man-hours. The man-hours estimates for the labor force series are based on an hours worked concept, i.e., hours spent at the establishment, thus excluding vacation and sick leave but including such things as rest periods and standby time.

Since compensation data are derived primarily from establishment payroll records, when relating labor productivity measures to hourly compensation, the appropriate series is the one based on establishment man-hours. On the other hand, when examining the relationship between productivity changes and displacement of workers, since the employment and unemployment measures are based on the household survey, the more consistent output per man-hour measure is the one based on labor force data.

In addition to the current indexes of output per man-hour published by the BLS, John Kendrick of the National Bureau of Economic Research has published indexes of output per man-hour for the private economy and major sectors (as well as total factor productivity) which include a series that makes adjustments for changes in the composition of man-hours.[9] Using average hourly earnings for weighting man-hours at the industry level he derives an index of output per weighted man-hour. The basic man-hour data for this series are generally the same as those for the establishment series and the weights are also derived from BLS average hourly earnings data. These indexes presently cover the period 1887 to 1966.

Edward Denison of the Brookings Institution has published measures of output per labor input in the form of growth rates for selected periods, the most recent being 1950-62.[10] These measures also take into account changes in the quality of labor; however, the procedure differs from Kendrick's. Adjustment based on age, sex, education, and other changes in the labor force are applied to basic employment and man-hours measures to derive labor input reflecting changes in quality. These measures are available only at the national level.

Industry measures. In addition to the indexes for the private economy and major sectors, the BLS publishes annually indexes of output per man-hour for selected industries.[11] At the present time, measures for about 40 manufacturing and nonmanufacturing industries such as steel, motor vehicles, railroad transportation, coal, etc., are prepared.

The output measures for these indexes are developed by combining the data on quantities of commodities or services within the industry with fixed period weights. As mentioned earlier, man-hour weights would be preferred for developing these measures and insofar as possible these are used. However, where such information is not available, other weights such as unit labor costs, or unit value (price) are used. These substitutions are introduced on the assumption that unit values are good commodities in an industry.

In addition, for some industries where it is not possible to obtain any quantity information, indexes of deflated value of output are developed. For these industry measures current dollar value estimates are divided by indexes of price change for the industry to derive a real output measuer. The adequacy of these measures is dependent on the quality of the price measure.

The labor input data for these measures are establishment man-hours. As in the aggregate measures, they are derived from payroll records and for the most part are based on an hours paid concept. For manufacturing industries, however, additional man-hours information is available in terms of hours at the plant. These data which theoretically exclude vacation, holdiays, and such leave hours are closer in concept to an hours worked measure. Unfortunately, the information on plant man-hours is usually not as current as that from other sources on establishment man-hours.

Capital productivity

Measures of output per unit of capital are not available on a current basis. Historical measures have been developed by a number of researchers.

Separate estimates of capital stock and hence measures of capital productivity are available for the private economy from sources such as the National Industrial Conference Board, National Bureau of Economic Research, and many economists doing research in production analysis. In addition, the Office of Business Economics prepares 12 different capital series depending on alternative options for service lives, depreciation, and

[9] John W. Kendrick, *Productivity Trends in the United States*, Princeton University Press, 1961.
[10] Edward F. Denison, op. cit.
[11] *Indexes of Output per Man-Hour, Selected Industries, 1939 and 1947-70* (BLS Bulletin 1692).

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adjustment for price change. These estimates are constructed within the framework of the national accounts and are consistent with output measures used for labor productivity in the private economy. However, the variation among these series gives different results for the growth of capital productivity.

The OBE estimates are prepared annually for the private economy, farm, manufacturing, nonfarm, and nonmanufacturing. They include equipment and nonresidential structures, but exclude such items as housing, motels, and hotels.

These capital stock series are developed using the perpetual inventory method. That is, each new piece of equipment or structure is added into the stock estimates and remains there until retired from use. Retirements of assets are based on mean useful service lives published in the Internal Revenue Services Bulletin of Service Lives of Assets. Because the latter are believed to overstate asset lives, OBE prepares estimates of capital series either based on Bulletin F or 85 percent of Bulletin F service lives.

Net capital measures are derived using either straight line or double declining balance depreciation.

Most other capital series are developed in a manner similar to the OBE measures with other variations on mean service lives and methods of depreciating assets.

Combined factor input productivity

The second group of productivity measures—those which relate output to several factors—involve the weighting together of the quantities of the separate factors. For the most part, these measures have been limited to output per unit of capital and labor combined.

Just as the separate components of an output index must be combined with appropriate weights, the separate components of the input measure also must be appropriately weighted together. Capital and labor can be aggregated using their unit costs (e.g., wages, rate of returns of capital) in a base year as weights. These weights can also be viewed as the proportion of current dollar output earned by each input (factor share) in a base period.

Two sources of combined factor input or total factor productivity measures exist—the work done by John Kendrick for the National Bureau of Economic Research and that by Edward Denison in his work on sources of growth.

Kendrick provided annual measures for the period 1889 to 1957, and more recent measures, 1957-69, will be available early in 1972. Estimates cover the private economy and are based on GNP output measures. Separate measures were made for farm, manufacturing, trade, finance, transportation, public utilities, and services and for selected industries within these major groups.

Labor input is measured in man-hours and adjusted for quality change using industrial hourly earnings. Capital includes the net stock of structure, plant equipment, inventories, working capital and land. The capital measures do not include quality inprovements which can occur because of technical advance. The capital and labor input are added together with factor prices as weights. The base period for the weights was changed periodically to reflect economic conditions of the various subperiods under analysis.

The combined factor measure developed by Edward Denison relates net domestic product (excluding depreciation) to weighted sum of capital and labor. The weights are the base period share of dollar output of each of these inputs. He also periodically shifted the base period for the factor shares to reflect current economic conditions. Denison's analysis covers the total economy for the 1919-62 period, and he is currently updating his work.

His labor input is employment adjusted for quality change using relative earnings for selected age-sex-education groups. He also adjusts the labor input for intensity of effort as reflected in varying lengths of the workweek. His assumption is that as the workweek declines productivity improves because the worker is less fatigued and can work more diligently.

RECOMMENDATIONS

Within the general constraints imposed on all users of economic data, productivity measures for the total private and private nonfarm economics and for selected major sectors (manufacturing, mining, trade, transportation, communication, and public utilities) are reliable and useful for economic analysis. Conversely, productivity measures for construction and service-type industries are not reliable measures for identifying either the magnitude or direction of change in productivity for the reasons outlined above. To improve these measures, additional information must be developed in two areas—the data base from which output, input, and price statistics are compiled, and the conceptual base upon which the output and price data are developed.

Additional price information

More and better price information in the service and construction industries is of prime urgency. In construction, work is currently underway by the Census Bureau to develop price measures in order to improve the measures of the real volume of residential construction put in place. Additional research is also necessary for nonresidential construction. In the service sector, more adequate

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and extensive price information on personal services is needed as well as the expansion of wholesale prices to include business services. The BLS at the present time is trying to develop an index of the general price level. The development of this index will materially assist productivity measurement because it will require the collection of a wider range of service prices.

More work is also needed in collecting data on durable equipment (such as heavy machinery and aircraft) which is highly differentiated and often custom-made.

Another recommendation is to have timely (quarterly and annually) estimates on the imputed rental value of owner occupied housing so that it may be excluded from the output estimate and not bias productivity measurement.

Better man-hour and capital data

Input data also need to be improved. Most important to productivity measurement would be better estimates for certain components of labor input. This would entail estimating supervisory hours in nonmanufacturing and expanding employment sampling coverage so that resultant data refer to the entire month rather than 1 week. Adjustment for changes in labor quality calls for more detailed information on occupational wages and man-hours. Some research is being carried out using occupational and wage data to account for some changes in labor quality, but it is necessary to develop a more integrated system for collection than in currently in effect.

Capital information is also needed to make a more complete analysis of factors affecting productivity growth. Of paramount importance are better data on changes in the quality of capital equipment and the length of service lives.

The concepts used to define output need to be changed to conform to a productivity framework. This is particularly true of government and households and institutions where actual output definitions are needed rather than merely relying on an employment measure.

Financial intermediaries also present definitional problems. For example, banking output is currently measured as liquidity. If the output reflected changes in the number of transactions weighted by some value measures, it would be more compatible with the inputs and provide a means for making a better productivity measure.

These recommendations will not solve all of the problems of productivity measurement. However, they will certainly improve the output and related input measures and thereby make productivity a more viable tool for economic analysis.

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Which Productivity? Perspective on a Current Question

SOLOMON FABRICANT*

"WHEN I USE A WORD," Humpty Dumpty could say to Alice in the Wonderland spun out of Lewis Carroll's dreams, "it means just what I choose it to mean—neither more nor less." In the everyday world in which we have to live, we cannot afford this individual freedom of choice. Yet everyone seems to interpret the word "productivity" in the light of his own experience and interests, and because these vary, productivity means different things to different people and they use the word differently. Confusion results. Only by discussion and explicit definition can the confusion be cleared up or avoided.

The same objective—to discuss and clarify the meaning of productivity—brought people together in 1946 at the first productivity conference sponsored by the Bureau of Labor Statistics and the Bureau of the Budget.[1] Since 1946, much has been done by the BLS and others to deepen the public's understanding of productivity and productivity change. But education is a perennial task. The rapid growth of Russia and other countries, widespread concern over inflation and the international balance of payments, the use of improvement factors in wage negotiations and contracts—these events since 1946 have stimulated greater interest in the rate and process of productivity change and thus in the meaning and measurement of productivity.

The subject of productivity is large; therefore, I shall direct attention to two main points. One is the variety of productivity concepts and measurements and thus the need to be explicit. The other is the dependence of concept on purpose: The concept must be appropriate to the use to which the productivity measurement is put.

Variety of Concepts and Measurements

To illustrate the variety of concepts and measurements attached to the word "productivity," let us ask an apparently specific question and see some of the answers that can be given to it. The question: What has been the average rate of growth in the Nation's productivity over the period 1947–57? The answers, taken from a study by the National Bureau of Economic Research,[2] are as follows: (1) 3.4 percent per annum, if we measure the rate of growth by the average annual increase in real gross national product per unweighted man-hour, in the private economy; (2) 3.1 percent per annum, if we shift from product per unweighted to product per weighted man-hour, otherwise keeping everything else the same; (3) 2.3 percent, if we shift further to product per weighted unit of man-hours and tangible capital combined, still keeping everything else the same; and (4) about 2.0 percent, if we measure the rate for the entire economy, including government—which requires even bolder estimation than do the preceding measures.

This is not an exhaustive list of all the "answers" even from this single source; and, of course, inclusion of the concepts and calculations of other statisticians would add to the variety. But enough has been cited to make the point: Without specification of its content, the word "productivity"—even the phrase "national productivity"—can mean more than one thing.

In concept, productivity is always a ratio of output to input, and a productivity index is always the ratio for one period (or place) relative to the corresponding ratio for another period (or

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This article is based on a paper presented by Dr. Fabricant at discussions on productivity held by the Bureau of Labor Statistics in 1960.

[1] *Summary of Proceedings of Conference on Productivity, October 28-29, 1946* (BLS Bulletin 913, 1947).

[2] John W. Kendrick, *Productivity Trends in the United States* (Princeton, N.J., Princeton University Press for the National Bureau of Economic Research, Inc., 1961), ch. 3 and app. A.

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place). But output can be defined broadly to cover the Nation as a whole, for example, or narrowly to cover a single industry. Input can refer to the simple sum of all man-hours worked, or to the weighted sum of man-hours (in which an hour put in by a skilled worker is counted as more than the hour put in by an unskilled worker), or to the weighted sum of the hours served by both labor and capital goods.

But modifying the noun "productivity" by appropriate adjectives and defining our terms, at least at the outset of each discussion, is only part of what needs to be done. Since productivity concepts and measurements vary, we must also choose among them before starting discussion. The choice depends on the purpose, for not every productivity concept is appropriate to every purpose.

Let us consider two uses of productivity concepts and measurements—in the analysis of output change and in wage determination or analysis. These are distinct purposes and require quite different concepts of productivity.

Analysis of Output Change

As a step in its analysis, output change may be viewed as resulting from change in each of two components. One is change in input, that is, the total quantity of resources used to turn out the product. The other is change in productivity, in the sense of change in the efficiency with which the resources are used to turn out the product—a change which results from change in technology, economic organization, and the other determinants of economic efficiency. Measurement of these components provides information on the quantitative contribution—the importance—of each. The combination of both kinds of change—in input and in productivity—equals the change in output.

In this analysis of output, the appropriate input is not the input of some of the resources used, but of all resources used. It is total input. The appropriate productivity is output per unit of total input. In effect, productivity is defined and measured in this way in order to make—

$$\text{Output} = \text{Total Input} \times \frac{\text{Output}}{\text{Total Input}}$$

Each term stands for an index number, in relative form, and all three index numbers are on the same base.

Change in efficiency in the use of resources cannot be determined by comparing change in output with change in a limited class of inputs. Therefore, output relative to a particular class of inputs—for example, labor alone or capital alone—would be inappropriate for the present purpose. Output per unit of plant and equipment may fall, for example, yet efficiency may rise if savings of labor's services per unit of product exceed the increase in the services of capital per unit of product. Similarly, an increase in output per man-hour may overstate the rise in efficiency if some of the laborsavings result from substitution of labor by capital. It is informative, of course, to see how each class of inputs is changing in relation of output. The index of output per unit of total input can, therefore, profitably be supplemented with the "partial" indexes of output per unit of labor input and of output per unit of capital input. But neither of these partial indexes is a very good substitute, in measuring efficiency, for the index that combines them.

If it is the Nation's total output that is being analyzed, the productivity index refers to national productivity—that is, real national product per unit of labor and capital used in the entire economy. If it is an industry's output that is being analyzed, the productivity index refers to the industry's productivity—its physical product relative to the labor and capital used by the industry.[3]

Wage Determination or Analysis

If the use of the productivity measure is in wage analysis, negotiation, or determination, the appropriate productivity concept is not output

[3] The industry's volume of production, it is assumed, is measured by its "net output." (Net output is roughly equivalent to deflated value added, with value added as defined in the Census of Manufactures.) The industry's production may also be measured by "gross output," and most frequently is so measured. (Gross output is equivalent to deflated value of product, with value of product equal to value added plus materials consumed.) In the latter case, the appropriate total input is labor plus capital plus materials, and efficiency is measured by gross output per unit of labor, capital, and materials combined.

The two productivity measures will seldom be equal. The second measure has some advantages over the first for measuring an industry's overall efficiency. The important point, however, is the need to be aware of the difference between the two and to avoid treating them as comparable.

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per unit of total input. Instead, it is output per man-hour and, particularly, output per weighted man-hour. (The wage index is presumed to be adjusted to exclude the effects of interindustry and intraindustry shifts in the relative importance of different classes of labor. If, as is usually the case, wages are measured in such a way as to reflect these shifts, the appropriate productivity concept is output per unweighted man-hour.) Further, the appropriate concept is output per weighted man-hour in the economy at large, whatever sector or industry happens to be under consideration.

The reason for choosing output per man-hour rather than output per unit of total resources is not that the economy's efficiency is unimportant in the determination of wages. It is very important. But it is also insufficient. Wage levels are also determined by other factors. Outstanding among these is the scarcity of labor relative to capital in the economy at large. Output per weighted man-hour combines both important factors, efficiency and labor scarcity. That is, the efficiency of the economy is measured by national product divided by weighted man-hours plus capital. The relative scarcity of labor is measured by weighted capital divided by weighted man-hours, or (more conveniently in the present context) by weighted man-hours plus capital divided by weighted man-hours. A combination of the two factors, obtained by multiplying them, yields national product per weighted man-hour:[4]

$$\frac{\text{National Product}}{\text{Weighted Man-Hours + Capital}} \times \frac{\text{Weighted Man-Hours + Capital}}{\text{Weighted Man-Hours}} = \frac{\text{National Product}}{\text{Weighted Man-Hours}}$$

The reason for choosing national output per man-hour even when the wage in a sector of the economy is under consideration is not because the efficiency and the capital per worker of the sector are irrelevant. They are relevant. In the long run, however, and as a rule even in the short run, they are far less relevant than national efficiency and capital per worker in the economy as a whole. They belong among the "qualifications" that must always be attached to any short list of wage factors, no matter how important, in order to explain, or perhaps justify, a discrepancy between change in wages and change in national output per man-hour.

Before turning to these qualifications, a bit more needs to be said about the rationale of the connection between national output per man-hour and wages.

Tie Between National Output Per Man-Hour and Wages. Technological advance and the other sources of rising national efficiency tend to cause all incomes, labor and property alike, to rise. An increase in national capital per worker tends to cause wages generally to rise more rapidly than returns per unit of capital. But it does not necessarily follow that the rise in wages must exactly equal, and may not exceed or fall short of, the combined rise in efficiency and labor scarcity. Nor does it necessarily follow, as parallelism between wages and output per man-hour implies, that the share of aggregate wages in national income (ignoring some differences between national product and national income) is constant, or—it is essentially the same thing—that wage cost per unit of product in the economy as a whole is constant. For these to follow, certain conditions must hold.

These conditions are: (1) Competition prevails in the markets for commodities, labor, and capital, so that increased efficiency and greater capital investment are free to bring appropriate increases in wages.[5] (2) The technical possibilities of substituting capital for labor are such that a change in capital per man-hour results in an equal change in the ratio of wages to the rate of return on capital, or—in terms of the measures we are using—a given percentage change in the ratio of total input to weighted man-hours brings an exactly equal percentage change in wages. (3) The two factors—efficiency and labor scarcity—are independent of one another, so that multiplying their indexes together gives an economically (not merely mathematically) correct combination of them. For example, technological change does not alter the relative scarcities and thus the

[4] If the wage index in question is not adjusted to exclude interindustry and intraindustry shifts, there is need to include a third factor—the quality of labor. This factor is measured by weighted man-hours divided by unweighted man-hours. The combination of all three factors is national product per unweighted man-hour.

[5] This means that national product per man-hour provides the competitive norm by which to judge actual wage behavior or wage proposals in noncompetitive situations.

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relative prices of labor and capital. These conditions—or assumptions, for that is what they are—need to be brought out into the open if the reasoning back of the tie between output per man-hour and wages is to be understood.[6]

Since many people have become accustomed to accepting output per man-hour as the productivity measure appropriate to wage discussion, the path we have followed in reaching it may strike them as rather tortuous. Why is it not sufficient to say, as has often been said, that output per man-hour is appropriate because it keeps constant the labor share in national income and the cost of labor per unit of product? It is insufficient if we are not told what economic forces and what technological and other characteristics of the economy keep, or tend to keep, the labor share and unit labor costs constant. It is necessary to say at least what has been said above.

Laying bare some of the assumptions underlying the use of output per man-hour in wage discussion raises questions about their validity and the reservations that need to be attached to this use. So does the historical record.

Historical Record. The long-term record does suggest something close to parallelism between wages in various industries and national output per man-hour, and, therefore, a greater rise in wages generally than in national output per unit of total input.[7] However, relative trends over shorter periods are not quite the same as over the long period for which the record is available. Further, while wages in different industries have moved up together, there have been differences in the rates of increase. From one point of view the similarities are more striking than the differences, but the latter are not negligible. This means that the wages of some industries have risen significantly more, and of others, less rapidly than national output per man-hour, in the longer as well as the shorter period. Also, the differences do not seem closely correlated with such clues as there are to the presence of monopoly. Even if the conditions specified above hold for the "average industry" and the "average period," there is little reason to suppose that they hold for every industry in every period.

While the historical record suggests that the assumptions noted (or alternative sets of assumptions that would yield the same outcome) are, on the whole, not too wide of the mark, it also supports the case for dwelling on the qualifications.

Indeed, even the hastiest backward glance reminds us that up to this point our attention has been confined to real wages. In a regime of rising (or falling) prices, another major factor affecting wages is the price trend—and when the price level is moving rapidly, this can be the predominant factor.[8] Explicit account can be taken of it by combining the price index with the other factors considered. This would yield an index of value (not volume) of national output per man-hour, and this also might be called a productivity index. But there seems to be little advantage in doing so.

Necessary Qualifications. History, and economic theory as well, remind us also of other things that may not be overlooked. I can discuss these here only briefly.

First, changes in technology, in tangible capital per worker, in the quality of labor, and even in the cost of living take time to work out their effects in the economy and make their impact on wages. This is true even in a competitive economy and even with such allowance as needs to be made for the influence of expectations on the lags. Not each industry in the economy, nor the economy

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[6] In the technical language of economics, the conditions are: (1) competition, so that the wage is equal to the marginal product of labor; (2) a production function of such shape that the elasticity of substitution between labor and capital is unity, so that a given percentage rise in the ratio of capital to labor is accompanied by an exactly equal percentage decline in the marginal rate of substitution of capital for labor; (3) neutrality of change in efficiency. (In most formal mathematical presentations of these conditions, use is made of the weighted geometric mean of inputs, rather than the weighted arithmetic mean that is implied in the text. According to available calculations, the difference between the two means is slight.)

[7] Over the period 1889–1957, and for the private domestic economy as a whole, the average annual percentage rates of change are as follows:

Real gross national product per weighted unit of man-hours and tangible capital	1.7
Weighted man-hours and real tangible capital (total input) per weighted man-hour	.3
Real gross national product per weighted man-hour	2.0
Weighted man-hours per unweighted man-hour	.3
Real gross national product per unweighted man-hour	2.3

These figures may be compared with:

Real hourly earnings, all workers (including proprietors and family workers)	2.4
Real hourly earnings, wage earners in manufacturing	2.3

Because the hourly earnings indexes are unadjusted for the shifts noted above, the productivity index comparable with the wage indexes is real gross national product per unweighted man-hour.

The approximate character of the estimates must be kept in mind; see my *Basic Facts on Productivity Change* (New York, National Bureau of Economic Research, Inc., 1959), Occasional Paper No. 63, pp. 29–37.

[8] Whether and what the "wage-push" contributes to inflation cannot be considered here.

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as a whole, is ever in full equilibrium either in the present or in the base period with which the present is compared. Consider, for example, an industry in which output per man-hour has begun to rise more rapidly than in the Nation at large. More often than not, its output will respond by rising more rapidly than national product, and its prices, by falling relative to the general price level. If the rise in its output is at a rate sufficient to cause its demand for labor to grow relatively, wages in the industry will tend to be higher than in other industries, that is, its wages will tend to rise more rapidly than national output per man-hour. If its output does not expand rapidly enough, labor demand will decline relatively, and the industry's wages will tend to be lower than in other industries, that is, its wages will tend to rise less rapidly than national output per man-hour. With appropriate changes, much the same qualification must be made for industries in which capital per worker is rising more or less rapidly than in the economy at large.

Second, while the quality of labor has generally risen as skills have improved and education has spread, the rate of increase has varied among industries and occupations. This, too, will affect the relation between a particular wage and national output per man-hour. So, also, will relative changes in the "noneconomic" advantages and disadvantages attached to a job and changes in the values put on them.

Third, with government—and the taxes government levies, the transfers it makes, and the services it renders—economically so much more important now than in earlier periods, changes in the structure and level of taxes and of government expenditures also significantly affect, at least in the long run, the relation between wages and national output per man-hour. In addition, the difficulties of measuring wages and productivity are aggravated. This explains the prevailing custom of using indexes for the "private economy" to represent national productivity.

And fourth, even for a given concept, productivity measurements may differ because sources of data differ and because of differences in the ways in which gaps in the data are filled. The difference between Census labor force data and BLS establishment data on man-hours provides an example. Further, the trend in productivity, even with the concept and source of data specified, depends on the particular period covered, for productivity does not advance evenly from one year to another. For example, if the period chosen begins with a trough and ends with a peak in business, the rate of increase in productivity will almost always be higher than if the period begins and ends in the same business cycle phase.

I must entirely pass over other troublesome points that arise when we ask the question, "Which productivity?" These include the extent to which labor and tangible capital adequately account for total input; the measurement of tangible capital input and of labor quality; the treatment of unemployed resources; the terms of foreign trade, which affect the Nation's productivity as well as its productivity measures; and the relative merits of different formulas for particular purposes, in which the choice between "base" and "given" years in selecting weights is only one element. Most of these and the other points raised deserve more intensive study than has yet been given to them.

It should be evident by now, however, that the assumptions involved in applying national output per man-hour in wage negotiation, determination, or study are many, and that they do not hold fully in every period and in every situation.

Summary. The index of national output per man-hour is highly useful because it summarizes the most important general factors that determine changes in wages in a competitive society. It does not cover all the relevant factors, it is true; therefore, deviations of wages from national output per man-hour may be expected to crop up everywhere. But because it does cover the most important general factors, in the absence of monopoly large deviations should be infrequent. The bigger the deviation, the more reason there must be to question and inquire into it. However, to understand the difference between a particular wage movement or proposal and the current trend of national output per man-hour, and to judge it, requires more than the index of output per man-hour.

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Part II. Productivity Trends in the Business Economy

This section examines the BLS measures of output per hour of all persons engaged in production and of multifactor productivity for the business economy. Developments in output per hour and in multifactor productivity in the business sector over the last three decades are outlined. The slowdown in the rate of productivity improvement during the 1970's is also explored.

Description of Measures for the Business Economy[1]

Productivity and related measures are prepared for the following sectors of the U.S. economy:

Quarterly and annual measures
Business sector
Nonfarm business sector
Nonfinancial corporations
Manufacturing, total, durable, nondurable

Annual measures only
Agriculture
Mining
Transportation
Communications
Utilities
Wholesale and retail trade
Finance, insurance, and real estate
Government enterprises

The Bureau's output per hour measures are constructed as the ratio between gross domestic product—GDP—originating in the private business economy and its subsectors, and the corresponding hours of all persons engaged in each sector.[2] The changes through time in these major indexes reflect efficiency in the use of labor, and indirectly, the effect of other input factors in the domestic production of goods and services. The changes in the productivity and related measures through the business cycle typically show patterns which differ substantially from those found in long-term movements, and, therefore, are the objects of special analytic studies.

Labor input measures are based primarily on BLS establishment payroll data on employment and hours and reflect hours at work and paid time off for vacations, holidays, and sick leave as well. A survey has been introduced to develop a set of labor input measures based on hours at work and will be used to extend the present series.

Indexes of compensation per hour measure the hourly cost to employers of wages and salaries, as well as supplemental payments, which include employers' contributions to social security, unemployment insurance taxes, and payments for private health insurance and pension plans. Measures of real compensation per hour reflect the adjustment of hourly compensation for changes in the Consumer Price Index for All Urban Consumers (CPI-U).

Unit labor cost measures the cost of labor input required to produce one unit of output and is derived by dividing compensation in current dollars by output in constant dollars. Unit nonlabor payments measure the cost of nonlabor items such as depreciation, rent, interest, and indirect business taxes, in addition to corporate profit and profit-type income of proprietorships and partnerships.

Earlier this year, the Bureau began a program of multifactor productivity measurement to supplement the labor productivity measures and to provide additional insights into productivity growth and economic changes. This program is an outgrowth of analytic studies undertaken by the Bureau investigating some of the factors contributing to productivity growth.[3] The multifactor productivity measures for the business and nonfarm business sectors are based upon capital and labor inputs.

In aggregate sectors, productivity changes through time reflect movements within the various component industries as well as shifts in the relative importance of each of the industries. For example, changes in labor productivity and multifactor productivity are influenced by the relative shift of inputs (labor and capital) from low- to high-productivity industries and by productivity changes in the component sector. Within industries, other shifts occur which are not accounted for ade-

[1] A more detailed discussion of BLS measures of productivity and related variables, such as compensation per hour, unit labor costs, output, etc., may be found in the *BLS Handbook of Methods,* Bulletin 2134-1, December 1982.

[2] Gross domestic product is gross national product less the net return on foreign investments. Net return on foreign investments is considered as originating in the "rest-of-world" sector.

[3] J.R. Norsworthy, Michael Harper, and Kent Kunze, "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors." See p. 30 of this reader.

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quately—changes in income and tastes, for example, may contribute to shifts in consumption patterns to higher quality goods, or to services rather than goods.

Short-term movements in productivity and unit labor costs often result from cyclical variation in output; this tends to distort the long-term relationship between output and labor input, as noted below, or output and multifactor input. A number of studies are being conducted to separate cyclical from long-term productivity movements.

Indexes of output per hour, compensation per hour, and related cost data are published quarterly in two series of BLS news releases: "Productivity and Costs in the Business Sector," and "Productivity and Costs in Nonfinancial Corporations." In addition, quarterly and annual analyses are published regularly in the *Monthly Labor Review.* Historical indexes of these and related data are available on request, as are detailed descriptions of data sources and computational procedures.

Indexes of output per hour and related cost data are published monthly in *Employment and Earnings* and the *Monthly Labor Review,* and in each edition of the *Handbook of Labor Statistics.*

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Multifactor Productivity in the Private Business Economy Since 1948

Productivity, as measured by output per unit of combined labor and capital inputs--multifactor productivity--rose an average of 1.5 percent per year from 1948 to 1981 in the private business sector, according to a new measure introduced today by the Bureau of Labor Statistics of the U.S. Department of Labor.

This new series shows the changes in the amount of labor and capital used in production (table A). As such it reflects the joint effect of many influences, including changes in technology, the level of output, utilization of capacity, the organization of production, managerial skills, as well as changes in the characteristics and efforts of the workforce.

The traditional productivity series--output per hour of all persons--reflects these influences and also the impact of changes in capital per unit of labor input. The new measure, therefore, supplements the existing measure by providing a basis for measuring that impact.

Over the 1948-81 period, when multifactor productivity increased 1.5 percent per year, the traditional productivity measure of output per hour rose 2.4 percent per year. Therefore, the growth in capital per hour contributed 0.9 percentage point to the growth in output per hour (table B).

The growth in multifactor productivity showed two distinct patterns: 2.0 percent per year from 1948 to 1973, but only 0.1 percent per year from 1973 to 1981. This slowdown reflected a falloff in output growth, coupled with a faster growth of combined inputs of labor and capital. The accelerated increase in inputs of labor and capital after 1973 was due to the faster increase in the hours of all persons since the annual rate of growth of capital was slower after 1973.

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Table A. Average annual rates of growth in productivity indexes and related measures by major sector, 1948 to 1981 1/

Measure	Private business 2/			Private nonfarm business 2/			Manufacturing		
	1948-1981	1948-1973	1973-1981	1948-1981	1948-1973	1973-1981	1948-1981	1948-1973	1973-1981
Productivity indexes:									
Output per hour of all persons.....	2.4	3.0	0.8	2.0	2.5	0.6	2.6	2.9	1.5
Output per unit of capital services....	-0.1	0.2	-1.0	-0.1	0.2	-1.1	-0.2	0.6	-2.6
Multifactor productivity 3/.....	1.5	2.0	0.1	1.3	1.7	0.0	1.8	2.2	0.4
Output.....	3.3	3.7	2.2	3.4	3.9	2.1	3.3	4.0	1.2
Inputs:									
Hours of all persons..	0.9	0.7	1.4	1.4	1.3	1.5	0.7	1.1	-0.2
Capital services.....	3.5	3.6	3.2	3.6	3.6	3.3	3.6	3.5	4.0
Combined labor and capital inputs 4/...	1.8	1.7	2.0	2.1	2.1	2.1	1.6	1.8	0.9

1/ Average annual rates based on compound rate formula.
2/ Excludes government enterprises.
3/ Output per unit of combined labor and capital input.
4/ Hours of all persons combined with capital service inputs index weighted by labor and capital shares.

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Table B. Average annual rates of growth in output per hour of all persons, the contribution of capital services per hour, and multifactor productivity, by major sector, 1948 to 1981 1/

Measure	1948-1981 (1)	1948-1973 (2)	1973-1981 (3)	Slowdown (4) (Col.2 -Col.3)
Private business 2/				
Output per hour of all persons	2.4	3.0	0.8	-2.2
Minus: Contribution of capital services per hour 3/	0.9	1.0	0.7	-0.3
Equals: Multifactor productivity 4/	1.5	2.0	0.1	-1.9
Private nonfarm business 2/				
Output per hour of all persons	2.0	2.5	0.6	-1.9
Minus: Contribution of capital services per hour 3/	0.7	0.8	0.6	-0.2
Equals: Multifactor productivity 4/	1.3	1.7	0.0	-1.7
Manufacturing				
Output per hour of all persons	2.6	2.9	1.5	-1.4
Minus: Contribution of capital services per hour 3/	0.8	0.7	1.1	0.4
Equals: Multifactor productivity 4/	1.8	2.2	0.4	-1.8

1/ Average annual rates based on compound rate formula.
2/ Excludes government enterprises.
3/ Change in capital per unit of labor weighted by capital's share of total output.
4/ Ouput per unit of combined labor and capital input.

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The following note briefly describes the major data sources and the procedures used in deriving the new BLS multifactor productivity indexes. More detailed information on the methods, limitations, and data sources are available on request from the Bureau of Labor Statistics.

Tables 1-6 include all the productivity and related indexes for each year.

Summary of Methods

The multifactor productivity indexes are derived by dividing an output index by an input index which is a weighted average of the hours of all persons and of capital services. The output indexes are computed from measures of constant dollar gross domestic product, derived from the national income and product accounts developed by the Bureau of Economic Analysis of the U.S. Department of Commerce.

The labor component of the input indexes is developed from measures of employment and average hours, drawn mainly from the BLS Current Employment Statistics program (the "establishment" survey) and the Current Population Survey (the "household" survey). The establishment survey provides information about employees on nonagricultural payrolls; the household survey about the self-employed, unpaid family workers, and those engaged in agriculture. The BLS has done considerable research on the effects on productivity growth of workforce composition (changes in the age, sex, and educational structure of the workforce). This work is not included in the measures published today because more research is required.

The capital services component of the combined input indexes is developed from measures of the stock of physical assets--equipment, structures, land, and inventories--and rental prices for each type of stock. The stock measures, in turn, are derived from data in the national accounts and other sources on investment, service lives, and capital deterioration functions. The rental prices are derived from data on depreciation costs and estimates of rates of return on the capital assets.

The labor and capital components of the input indexes are combined with weights which represent each component's share of total output. The index uses changing weights where the share in each year is averaged with the preceding year's value.

Data are presented for the private business, private nonfarm business, and manufacturing sectors. The private business sector, which accounts for about 80 percent of the gross national product includes all activities in the economy with the exception of general government, government enterprises, the "rest of world" sector, owner-occupied housing, nonprofit institutions, and private household employees. The private nonfarm business sector also excludes agriculture but includes agricultural services.

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The traditional productivity measure of output per hour slowed--dropping from a growth rate of 3.0 percent during the 1948-73 period to 0.8 percent from 1973 to 1981. Of this 2.2 percentage point falloff, 0.3 percentage point was the result of the slowdown in the growth of capital per unit of labor input. The balance--that of multifactor productivity growth--reflected the remaining influences.

Output per unit of capital services, another productivity measure introduced today, fluctuated between 1948 and 1981 but did not register a significant trend over the period as a whole (chart A).

Private nonfarm business. From 1948 to 1981, multifactor productivity growth in this sector averaged 1.3 percent annually as output rose 3.4 percent per year and combined labor and capital inputs increased 2.1 percent per year (table A).

As was the case for the private business sector as a whole, after 1973 there was a marked change in the trend. Multifactor productivity grew 1.7 percent annually from 1948 to 1973, but did not grow at all after 1973 (table B). Hence, all of the increase in output during the later period came from increased inputs of capital and labor.

The traditional productivity measure for the private nonfarm business sector, output per hour of all persons, rose 2.5 percent per year from 1948 to 1973, compared with 0.6 percent per year between 1973 and 1981. The 1.9 percentage point slowdown in output per hour in this sector partly reflects a 0.2 percentage point decline in the contribution of capital services per unit of labor input. Most of the slowdown, however, was due to the 1.7 percentage point falloff in multifactor productivity growth, which in turn reflected the impact of other influences.

As in private business, output per unit of capital input in the private nonfarm business sector fluctuated from year to year, but there was no evident trend between 1948 and 1981 (chart B).

Manufacturing. From 1948 to 1981, multifactor productivity grew faster in manufacturing than in the more comprehensive business sectors. There was a 1.8 percent annual gain, reflecting a 3.3 percent average rise in output coupled with a 1.6 percent annual increase in combined labor and capital inputs.

The falloff in the multifactor growth rate also occurred in manufacturing after 1973--from a rate of 2.2 percent during the 1948-73 period to 0.4 percent from 1973 to 1981 (table B).

The slowdown in the traditional output per hour indexes for manufacturing after 1973 was 1.4 percentage points, less severe than for the more comprehensive business sectors. Moreover, the growth of capital per hour in manufacturing accelerated after 1973. From 1948 to 1973 the growth in capital services per unit of labor contributed 0.7 percent per year to the growth in output per hour in manufacturing and, after 1973, 1.1 percent per year.

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Table 1. Private business sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/	3/	Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
	Indexes 1977=100							
1948	45.3	99.2	60.1	36.8	81.3	37.1	61.3	45.6
1949	46.0	93.6	59.4	36.1	78.6	38.6	60.8	49.1
1950	49.7	98.7	63.6	39.5	79.5	40.0	62.1	50.4
1951	51.2	100.2	65.1	41.8	81.8	41.8	64.3	51.1
1952	52.9	99.4	66.3	43.2	81.8	43.5	65.2	53.2
1953	54.6	100.7	68.0	45.1	82.6	44.9	66.4	54.3
1954	55.6	96.3	67.8	44.4	79.8	46.1	65.5	57.7
1955	57.8	100.9	70.7	47.9	82.9	47.5	67.8	57.3
1956	58.5	100.0	71.0	49.2	84.2	49.2	69.3	58.5
1957	60.0	97.9	71.6	49.7	82.9	50.7	69.4	61.2
1958	61.8	94.3	72.0	48.9	79.0	51.9	67.8	65.6
1959	63.9	99.3	74.9	52.5	82.1	52.9	70.0	64.4
1960	64.8	98.4	75.4	53.3	82.2	54.1	70.7	65.8
1961	67.0	98.0	76.9	54.2	80.9	55.3	70.5	68.4
1962	69.6	101.2	79.7	57.2	82.2	56.6	71.8	68.8
1963	72.3	102.6	82.0	59.7	82.7	58.2	72.9	70.4
1964	75.4	105.2	84.9	63.3	84.0	60.2	74.6	71.6
1965	78.1	107.8	87.6	67.6	86.7	62.8	77.2	72.4
1966	80.4	108.0	89.3	71.3	88.7	66.1	79.9	74.5
1967	82.3	104.9	89.6	72.9	88.6	69.6	81.4	78.5
1968	85.1	105.5	91.7	76.7	90.1	72.7	83.7	80.7
1969	85.3	103.7	91.3	78.9	92.5	76.1	86.5	82.3
1970	86.1	98.6	90.2	78.3	90.9	79.4	86.8	87.4
1971	89.2	98.1	92.2	80.6	90.4	82.2	87.5	91.0
1972	92.4	101.0	95.2	86.0	93.2	85.2	90.4	91.5
1973	94.7	103.0	97.5	91.8	96.9	89.1	94.1	92.0
1974	92.4	96.5	93.8	89.9	97.2	93.1	95.8	95.8
1975	94.5	91.9	93.6	88.0	93.1	95.7	94.0	102.8
1976	97.6	96.1	97.1	93.7	95.9	97.5	96.5	101.6
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.6	101.8	101.0	105.5	104.9	103.6	104.4	98.8
1979	99.6	100.3	99.9	107.8	108.3	107.5	108.0	99.3
1980	98.8	95.3	97.6	106.2	107.4	111.3	108.8	103.6
1981	100.6	95.0	98.6	108.8	108.2	114.5	110.3	105.8
	Average annual percent change 7/							
1948-73	3.0	0.2	2.0	3.7	0.7	3.6	1.7	2.8
1973-81	0.8	-1.0	0.1	2.2	1.4	3.2	2.0	1.8
1948-81	2.4	-0.1	1.5	3.3	0.9	3.5	1.8	2.6

See footnotes following table 6.

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Table 2. Private nonfarm business sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/	3/	Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
				Indexes 1977=100				
1948	51.2	98.1	64.6	35.6	69.6	36.3	55.1	52.2
1949	52.3	92.8	64.2	34.9	66.8	37.7	54.4	56.3
1950	55.6	98.4	68.2	38.3	69.0	39.0	56.2	56.5
1951	56.6	100.6	69.5	40.9	72.2	40.6	58.8	56.3
1952	58.0	99.7	70.4	42.2	72.8	42.4	60.0	58.2
1953	59.0	100.9	71.5	44.1	74.7	43.7	61.7	58.5
1954	59.9	96.2	71.0	43.2	72.1	44.9	60.8	62.3
1955	62.3	100.9	74.1	46.8	75.1	46.4	63.2	61.7
1956	62.5	100.1	74.0	48.2	77.0	48.1	65.1	62.5
1957	63.6	98.0	74.3	48.7	76.6	49.7	65.6	64.9
1958	65.1	94.0	74.3	47.8	73.4	50.8	64.3	69.3
1959	67.4	99.5	77.5	51.6	76.6	51.9	66.6	67.7
1960	67.9	98.4	77.6	52.3	77.0	53.2	67.5	69.1
1961	70.0	97.9	78.9	53.3	76.1	54.4	67.5	71.5
1962	72.5	101.3	81.7	56.4	77.8	55.7	69.0	71.6
1963	74.9	102.6	83.8	58.9	78.6	57.4	70.3	73.0
1964	77.8	105.5	86.7	62.7	80.5	59.4	72.3	73.8
1965	80.3	108.1	89.2	67.0	83.5	62.0	75.1	74.2
1966	82.2	108.7	90.7	71.0	86.4	65.3	78.3	75.7
1967	83.8	105.3	90.7	72.5	86.5	68.9	79.9	79.6
1968	86.7	106.0	92.9	76.5	88.2	72.1	82.3	81.7
1969	86.4	104.1	92.1	78.7	91.1	75.6	85.4	83.0
1970	86.8	98.6	90.7	77.9	89.7	78.9	85.9	88.0
1971	89.7	98.0	92.4	80.1	89.3	81.8	86.7	91.5
1972	93.0	101.1	95.7	85.8	92.2	84.8	89.7	92.0
1973	95.3	103.2	97.9	91.7	96.2	88.8	93.6	92.3
1974	92.9	96.5	94.1	89.7	96.6	93.0	95.4	96.3
1975	94.7	91.7	93.6	87.6	92.5	95.6	93.6	103.3
1976	97.8	96.1	97.2	93.6	95.7	97.4	96.3	101.8
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.6	101.9	101.1	105.7	105.1	103.7	104.6	98.7
1979	99.3	100.0	99.6	108.0	108.7	107.9	108.4	99.2
1980	98.4	95.1	97.3	106.2	108.0	111.7	109.2	103.4
1981	99.8	94.4	97.9	108.5	108.8	115.0	110.9	105.7
				Average annual percent change 7/				
1948-73	2.5	0.2	1.7	3.9	1.3	3.6	2.1	2.3
1973-81	0.6	-1.1	0.0	2.1	1.5	3.3	2.1	1.7
1948-81	2.0	-0.1	1.3	3.4	1.4	3.6	2.1	2.2

See footnotes following table 6.

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Table 3. Manufacturing sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/	3/	Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
	Indexes 1977=100							
1948	45.1	94.4	56.2	35.8	79.4	37.9	63.7	47.8
1949	46.9	86.0	56.0	33.9	72.4	39.5	60.6	54.5
1950	49.4	94.9	59.9	38.6	78.2	40.7	64.5	52.1
1951	51.1	99.6	62.3	43.0	84.2	43.2	69.1	51.3
1952	52.0	95.7	62.2	44.5	85.4	46.4	71.4	54.4
1953	52.9	98.6	63.5	47.5	89.8	48.2	74.8	53.7
1954	53.7	89.2	62.3	44.1	82.1	49.5	70.8	60.2
1955	56.4	95.8	65.9	48.9	86.6	51.0	74.2	58.8
1956	56.0	92.5	64.8	49.2	87.9	53.2	75.9	60.5
1957	57.1	89.6	65.1	49.5	86.5	55.2	76.0	63.8
1958	56.9	80.5	62.8	45.2	79.4	56.2	71.9	70.7
1959	59.6	89.2	67.0	50.5	84.7	56.6	75.4	66.9
1960	60.0	88.0	67.0	50.7	84.4	57.5	75.6	68.2
1961	61.6	86.9	68.0	50.7	82.3	58.3	74.6	70.9
1962	64.3	92.9	71.5	55.1	85.6	59.2	77.0	69.2
1963	68.9	98.3	76.3	59.6	86.5	60.7	78.2	70.1
1964	72.3	102.4	79.8	63.9	88.4	62.4	80.0	70.6
1965	74.5	107.3	82.8	69.8	93.6	65.1	84.3	69.5
1966	75.3	108.7	83.7	75.1	99.8	69.2	89.8	69.3
1967	75.3	101.1	81.8	75.0	99.6	74.2	91.7	74.5
1968	78.0	101.1	83.7	79.1	101.4	78.2	94.4	77.1
1969	79.3	100.5	84.6	81.7	103.1	81.3	96.6	78.9
1970	79.1	91.8	82.3	77.0	97.3	83.9	93.6	86.2
1971	83.9	92.4	86.0	78.7	93.7	85.2	91.5	90.9
1972	88.2	99.9	91.1	86.2	97.8	86.4	94.7	88.3
1973	93.0	108.2	96.8	95.9	103.2	88.6	99.1	85.9
1974	90.8	99.6	93.0	91.9	101.2	92.2	98.8	91.1
1975	93.4	89.4	92.2	85.4	91.4	95.5	92.6	104.4
1976	97.5	96.1	97.1	93.6	95.9	97.4	96.4	101.5
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.9	101.5	101.0	105.3	104.4	103.8	104.2	99.4
1979	101.6	99.5	101.0	108.2	106.5	108.8	107.2	102.1
1980	101.7	90.0	98.6	103.6	101.8	115.1	105.1	113.1
1981	104.5	87.5	99.9	105.9	101.3	121.1	106.0	119.5
	Average annual percent change 7/							
1948-73	2.9	0.6	2.2	4.0	1.1	3.5	1.8	2.4
1973-81	1.5	-2.6	0.4	1.2	-0.2	4.0	0.9	4.2
1948-81	2.6	-0.2	1.8	3.3	0.7	3.6	1.6	2.8

See footnotes following table 6.

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Table 4. Private business sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output 3/	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/		Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
	Percent change							
1949	1.6	-5.6	-1.1	-1.9	-3.4	4.0	-0.8	7.6
1950	8.2	5.5	7.2	9.4	1.2	3.7	2.1	2.5
1951	2.9	1.5	2.4	5.9	2.9	4.4	3.5	1.4
1952	3.4	-0.8	1.8	3.3	0.0	4.2	1.5	4.2
1953	3.3	1.3	2.6	4.4	1.1	3.1	1.8	2.0
1954	1.7	-4.3	-0.4	-1.8	-3.4	2.7	-1.4	6.3
1955	4.1	4.8	4.4	8.1	3.8	3.1	3.6	-0.7
1956	1.1	-0.9	0.3	2.6	1.5	3.6	2.3	2.0
1957	2.6	-2.1	0.9	1.0	-1.5	3.1	0.1	4.7
1958	3.1	-3.7	0.7	-1.6	-4.6	2.2	-2.3	7.1
1959	3.3	5.3	4.0	7.3	3.9	2.0	3.2	-1.9
1960	1.5	-0.8	0.6	1.6	0.1	2.4	0.9	2.3
1961	3.4	-0.5	2.0	1.7	-1.6	2.2	-0.3	3.8
1962	3.9	3.2	3.6	5.6	1.6	2.3	1.9	0.6
1963	3.8	1.4	2.9	4.4	0.6	2.9	1.4	2.4
1964	4.3	2.5	3.6	6.0	1.6	3.4	2.3	1.7
1965	3.6	2.4	3.1	6.8	3.1	4.3	3.6	1.1
1966	3.1	0.2	1.9	5.5	2.4	5.3	3.5	2.8
1967	2.3	-2.9	0.3	2.2	-0.1	5.3	1.9	5.4
1968	3.5	0.6	2.4	5.2	1.7	4.6	2.7	2.9
1969	0.2	-1.7	-0.5	2.9	2.7	4.7	3.4	1.9
1970	0.9	-5.0	-1.2	-0.8	-1.7	4.3	0.3	6.2
1971	3.6	-0.5	2.2	3.0	-0.6	3.5	0.8	4.1
1972	3.5	3.0	3.3	6.7	3.1	3.6	3.3	0.5
1973	2.6	2.0	2.4	6.6	4.0	4.6	4.2	0.6
1974	-2.4	-6.3	-3.8	-2.1	0.4	4.5	1.8	4.2
1975	2.2	-4.7	-0.2	-2.1	-4.2	2.7	-1.8	7.3
1976	3.3	4.5	3.8	6.5	3.0	1.9	2.6	-1.1
1977	2.4	4.0	3.0	6.7	4.2	2.6	3.6	-1.6
1978	0.6	1.8	1.0	5.5	4.9	3.6	4.4	-1.2
1979	-1.0	-1.4	-1.1	2.2	3.2	3.7	3.4	0.5
1980	-0.8	-5.0	-2.2	-1.6	-0.8	3.6	0.7	4.4
1981	1.8	-0.3	1.1	2.5	0.7	2.9	1.5	2.1

See footnotes following table 6.

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Table 5. Private nonfarm business sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/	3/	Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
	Percent change							
1949	2.2	-5.4	-0.6	-1.9	-4.0	3.7	-1.3	8.0
1950	6.3	6.0	6.2	9.7	3.2	3.5	3.3	0.3
1951	1.9	2.2	2.0	6.6	4.6	4.2	4.5	-0.4
1952	2.5	-0.9	1.2	3.4	0.9	4.3	2.1	3.4
1953	1.7	1.2	1.5	4.4	2.6	3.2	2.8	0.6
1954	1.5	-4.7	-0.6	-2.0	-3.5	2.8	-1.4	6.5
1955	4.0	5.0	4.4	8.4	4.2	3.3	3.8	-0.9
1956	0.3	-0.9	-0.1	2.8	2.5	3.7	3.0	1.2
1957	1.8	-2.0	0.4	1.2	-0.6	3.3	0.8	3.9
1958	2.4	-4.1	0.0	-1.9	-4.3	2.3	-2.0	6.8
1959	3.5	5.9	4.3	8.0	4.4	2.0	3.5	-2.3
1960	0.8	-1.1	0.1	1.4	0.6	2.6	1.3	2.0
1961	3.0	-0.5	1.7	1.8	-1.2	2.3	0.1	3.5
1962	3.6	3.4	3.5	5.9	2.2	2.4	2.3	0.2
1963	3.3	1.4	2.5	4.4	1.1	3.0	1.8	1.9
1964	3.9	2.8	3.5	6.4	2.4	3.5	2.8	1.1
1965	3.1	2.5	2.9	7.0	3.7	4.4	4.0	0.7
1966	2.4	0.5	1.7	5.9	3.4	5.4	4.2	1.9
1967	1.9	-3.1	0.0	2.1	0.2	5.4	2.1	5.2
1968	3.4	0.7	2.4	5.4	2.0	4.7	3.0	2.7
1969	-0.3	-1.8	-0.8	2.9	3.2	4.8	3.8	1.5
1970	0.4	-5.3	-1.6	-1.1	-1.5	4.5	0.5	6.0
1971	3.4	-0.6	2.0	2.9	-0.4	3.6	0.9	4.0
1972	3.7	3.2	3.5	7.0	3.2	3.7	3.4	0.5
1973	2.5	2.1	2.3	6.9	4.3	4.7	4.5	0.4
1974	-2.5	-6.5	-3.9	-2.2	0.4	4.7	1.8	4.3
1975	2.0	-5.0	-0.5	-2.4	-4.3	2.8	-1.9	7.4
1976	3.3	4.9	3.8	6.9	3.5	1.9	2.9	-1.5
1977	2.2	4.0	2.9	6.8	4.5	2.7	3.8	-1.8
1978	0.6	1.9	1.1	5.7	5.1	3.7	4.6	-1.3
1979	-1.3	-1.8	-1.5	2.1	3.5	4.0	3.7	0.5
1980	-0.9	-5.0	-2.3	-1.6	-0.7	3.5	0.7	4.2
1981	1.4	-0.8	0.7	2.2	0.8	3.0	1.5	2.2

See footnotes following table 6.

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Table 6. Manufacturing sector: Productivity and related measures, 1948-81. 1/

Year	Productivity			Output	Inputs			Capital per Hour of All Persons
	Output Per Hour of All Persons	Output Per Unit of Capital	Multifactor Productivity 2/	3/	Hours of All Persons 4/	Capital 5/	Combined Units of Labor and Capital Inputs 6/	
	Percent change							
1949	4.0	-8.9	-0.4	-5.2	-8.9	4.0	-4.9	14.1
1950	5.4	10.4	7.1	13.9	8.0	3.2	6.3	-4.5
1951	3.4	4.9	3.9	11.4	7.7	6.2	7.2	-1.4
1952	1.8	-3.9	-0.1	3.3	1.4	7.5	3.4	5.9
1953	1.7	3.0	2.1	6.9	5.1	3.7	4.7	-1.3
1954	1.6	-9.6	-2.0	-7.2	-8.6	2.7	-5.3	12.3
1955	5.0	7.5	5.8	10.8	5.5	3.1	4.7	-2.3
1956	-0.7	-3.4	-1.6	0.7	1.5	4.3	2.4	2.8
1957	2.1	-3.2	0.4	0.5	-1.5	3.8	0.1	5.4
1958	-0.4	-10.2	-3.4	-8.6	-8.2	1.7	-5.4	10.9
1959	4.8	10.8	6.6	11.7	6.6	0.8	4.8	-5.4
1960	0.7	-1.3	0.1	0.3	-0.3	1.6	0.3	1.9
1961	2.7	-1.2	1.5	0.1	-2.5	1.4	-1.4	4.0
1962	4.3	6.9	5.1	8.6	4.1	1.6	3.3	-2.4
1963	7.2	5.7	6.7	8.3	1.0	2.4	1.5	1.4
1964	4.8	4.2	4.6	7.1	2.2	2.9	2.4	0.6
1965	3.1	4.8	3.7	9.2	5.9	4.2	5.3	-1.6
1966	1.1	1.3	1.2	7.7	6.5	6.3	6.5	-0.2
1967	0.0	-7.0	-2.3	-0.2	-0.2	7.2	2.1	7.5
1968	3.5	0.0	2.4	5.5	1.9	5.4	3.0	3.5
1969	1.7	-0.6	1.0	3.4	1.6	3.9	2.3	2.3
1970	-0.2	-8.7	-2.7	-5.8	-5.6	3.2	-3.2	9.3
1971	6.1	0.6	4.5	2.2	-3.7	1.6	-2.2	5.5
1972	5.0	8.1	6.0	9.6	4.3	1.4	3.4	-2.8
1973	5.4	8.4	6.3	11.2	5.5	2.6	4.6	-2.8
1974	-2.4	-7.9	-3.9	-4.2	-1.9	4.1	-0.3	6.1
1975	2.9	-10.3	-0.9	-7.1	-9.7	3.5	-6.2	14.6
1976	4.4	7.4	5.3	9.6	4.9	2.0	4.1	-2.8
1977	2.5	4.1	3.0	6.9	4.2	2.7	3.8	-1.5
1978	0.9	1.5	1.0	5.3	4.4	3.8	4.2	-0.6
1979	0.7	-2.0	-0.1	2.7	2.0	4.8	2.8	2.7
1980	0.2	-9.5	-2.4	-4.3	-4.5	5.8	-1.9	10.7
1981	2.8	-2.8	1.4	2.3	-0.5	5.2	0.9	5.7

See footnotes following table 6.

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Footnotes, Tables 1-6

SOURCE: Output data from Bureau of Economic Analysis (BEA), U.S. Department of Commerce, and the Federal Reserve Board. Compensation and hours data from the Bureau of Labor Statistics, U.S. Department of Labor, and BEA. Capital measures are based on data supplied by BEA and U.S. Department of Agriculture.

(1) The private business sector includes all of Gross National Product except the rest-of-world sector, the rental value of owner-occupied real estate, the output arising in nonprofit organizations, the rental value of real estate occupied by nonprofit organizations, the output of paid employees of private households, government, and the statistical discrepancy in preparing the national income accounts. The private nonfarm business sector also excludes farms, but includes agricultural services.

(2) Output per unit of combined labor and capital inputs.

(3) Gross Domestic Product originating in the sector, in constant dollars.

(4) Paid hours of all employees, plus the hours of proprietors and unpaid family workers engaged in the sector.

(5) A measure of the flow of capital services used in the sector.

(6) Hours of all persons combined with capital input, using labor and capital shares of output as weights.

(7) Average annual percent change based on compound rate formula.

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The Slowdown in Productivity Growth: Analysis of Some Contributing Factors

LABOR PRODUCTIVITY in the private business sector grew at an annual rate of 1 percent from 1973 to 1978, about one-third of its rate of growth from 1948 to 1965. The effects of this slowdown were both substantially reduced economic growth and higher prices. A comprehensive analysis of recent economic growth has been made by Edward F. Denison, who examined the effects of regulation on growth in a framework that assesses the contributions from various potential causal factors.[1] Our approach is different from his in several respects, depending primarily on the definition of output and the measurement of capital input.[2] Several other studies have focused on particular issues in the productivity puzzle, such as analyses of the effects of capital formation, energy, labor force composition, and intersectoral shifts of labor.[3]

This paper investigates productivity in the private business sector for which quarterly labor productivity and cost statistics are published by the U.S. Bureau of Labor Statistics (BLS). The basic methodology weights growth rates of capital and labor inputs by their shares in gross domestic product of this sector. Although growth in labor productivity is the target for explanation, the framework includes the contribution of multifactor productivity growth—the Hicks-neutral residual. The measurement techniques draw primarily on the work of Denison and Dale W. Jorgenson, as outlined below.

The factors we examine as possibly contributing to the slowdown are limited to those that can be quantified and adapted for inclusion in a national accounts framework. Therefore, we do not explore such issues as deterioration of the work ethic, and any effect from such unmeasured phenomena will presumably appear in the residual of our analysis. In an alternative framework based on regression analysis, one could try to measure such phenomena because the standards for quantifying them could be relaxed.[4] However, the collinearity in single-equation regression models makes the coefficients associated with any single factor highly variable, depending greatly upon the other factors included in a particular specification. A multiple-equation, simultaneous model might be attempted; but it would be difficult to include a number of possible explanatory factors in a framework that allows for variable elasticities of substitution.

We examine, in addition, the existence and timing of the productivity slowdown and its pervasiveness among major industry sectors of the economy. And we estimate the contribution to this slowdown of changes in the composition of the labor force, changes in capital-labor ratios, trends in the ratio of hours worked to hours paid, interindustry shifts of capital and labor, capital expenditures for pollution abatement, and increases in energy prices. Most of these effects are analyzed by interpreting them as augmenting or abating the effective input of capital or labor.

A general point about the analysis of the slowdown needs to be made at the outset. For a particular phenomenon to contribute to a slowdown in productivity growth, its effects must be greater in the slowdown period than in the reference period. We therefore need data to estimate the effects in both periods in order to determine any contribution to the slowdown. It is not sufficient that a particular negative factor is at work during the slowdown; it must be working demonstrably harder than before.

The Dimensions of the Slowdown

Peter Clark, after adjusting the labor productivity series for cyclical movements, selected the time periods 1948–55, 1955–65, 1965–73, and 1973–77 for analysis.[5] The endpoint years, except for 1977, are peaks in Clark's cyclically adjusted labor productivity. The year 1965 has additional claims as a watershed year: it marked the onset of major Vietnam War deficit financing and increasing inflation. And at about that time the first cohort from the postwar "baby boom" entered the labor force. We

Table 1. Rates of Growth of Labor Productivity, Output, Capital, and Hours, and Ratio of Investment to Output, Private Business Sector, Selected Periods, 1948–78[a]
Annual average, in percent

Item	*1948–65*	*1965–73*	*1973–78*
Labor productivity	3.32	2.32	1.20
Gross domestic product	3.71	3.77	2.62
Net capital stock[b]	2.62	3.67	2.05
Total hours of labor input[c]	0.38	1.44	1.42
Ratio of gross private domestic investment to gross domestic product	12.3	13.5	12.8

Source: Computed by authors using data from the U.S. Bureau of Economic Analysis and the U.S. Bureau of Labor Statistics.
a. Output, investment, and the capital stock are measured at 1972 prices.
b. The method of aggregation used is direct aggregation. See table 4.
c. Measured as hours paid.

1. Edward F. Denison, "Effects of Selected Changes in the Institutional and Human Environment Upon Output Per Unit of Input," *Survey of Current Business*, vol. 58 (January 1978), pp. 21–44.

2. Edward F. Denison, *Accounting for United States Economic Growth, 1929–1969* (Brookings Institution, 1974).

3. For capital formation see Peter K. Clark, "Capital Formation and the Recent Productivity Slowdown," *Journal of Finance*, vol. 33 (June 1978), pp. 965–75; *Economic Report of the President, January 1978*, pp. 48–58; and J. R. Norsworthy and Michael J. Harper, "The Role of Capital Formation in the Recent Productivity Growth Slowdown," Working Paper 87 (Bureau of Labor Statistics, January 1979). For energy see Edward A. Hudson and Dale W. Jorgenson, "Energy Prices and the U.S. Economy, 1972–1976," *Data Resources Review*, vol. 7 (September 1978), pp. 1.24–1.37; and George L. Perry, "Potential Output: Recent Issues and Present Trends," in Center for the Study of American Business, "U.S. Productive Capacity: Estimating the Utilization Gap," Working Paper 23 (Washington University, CSAB, December 1977), pp. 1–20 (Brookings Reprint 336). For labor force composition and intersectoral shifts of labor see Jack Beebe, "A Note on Intersectoral Shifts and Aggregate Productivity Change," *Annals of Economic and Social Measurement*, vol. 4 (Summer 1975), pp. 389–95; George L. Perry, "Labor Force Structure, Potential Output, and Productivity," *BPEA, 3:1971*, pp. 533–65; William D. Nordhaus, "The Recent Productivity Slowdown," *BPEA, 3:1972*, pp. 493–526; Michael Grossman and Victor R. Fuchs, "Intersectoral Shifts and Aggregate Productivity Change," in American Statistical Association, *Proceedings of the Business and Economic Statistics Section* (Washington, D.C.: ASA, 1972), pp. 66–75; and J. R. Norsworthy and L. J. Fulco, "Productivity and Costs in the Private Economy, 1973," *Monthly Labor Review*, vol. 97 (June 1974), pp. 3–9.

4. Robin Siegel, "Why Has Productivity Slowed Down?" *Data Resources Review*, vol. 8 (March 1979), pp. 1.59–1.65.

5. Clark, "Capital Formation."

Reprinted from *Brookings Papers on Economic Activity*, 2:1979.

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Table 2. Growth of Labor Productivity and Share of Labor Input in the Total Private Business Economy, by Sector, Selected Periods, 1948–78
Annual average, in percent

Sector	*Growth of labor productivity*			*Share of total labor hours*		
	1948–65	*1965–73*	*1973–78*	*1948–65*	*1965–73*	*1973–78*
Private business	3.2	2.3	1.1	100	100	100
Agriculture, forestry, and fisheries	5.5	5.3	2.9	12	6	5
Mining	4.2	2.0	−4.0	1	1	1
Construction	2.9	−2.2	−1.8	6	7	7
Manufacturing	3.1	2.4	1.7	30	32	30
Durable goods	2.8	1.9	1.2	17	19	18
Nondurable goods	3.4	3.2	2.4	13	13	12
Transportation	3.3	2.9	0.9	5	5	4
Communication	5.5	4.8	7.1	1	2	2
Electric, gas, and sanitary services	6.2	4.0	0.1	1	1	1
Trade	2.7	3.0	0.4	23	25	26
Wholesale	3.1	3.9	0.2	6	7	7
Retail	2.4	2.3	0.8	17	18	19
Finance, insurance, and real estate	1.0	−0.3	1.4	5	6	6
Services	1.5	1.9	0.5	12	14	16
Government enterprises	−0.8	0.9	−0.7	2	2	2

Source: Bureau of Labor Statistics. Productivity data for services, construction, and finance, insurance, and real estate are unpublished.

adapted Clark's time periods (which were based initially on quarterly data) by combining the first two periods and extending the last one to 1978. The present evidence that real output is leveling off or declining during 1979 suggests that 1978 will be a reasonable endpoint for the analysis.

For each of our reference periods, table 1 shows the rates of growth of output, labor and capital input, and labor productivity in the private business sector—the largest sector for which the BLS publishes productivity statistics. The slowdown in the growth of labor productivity is evident in the last two periods. The growth of the capital stock is examined carefully below. It is worth noting here that it slowed substantially in the last period, even though the ratio of investment to gross product was slightly higher than in 1948–65. The growth rate of output does not explain variations in this investment fraction the way a simple accelerator model would predict. However, accelerator effects might help to explain part of the slowdown in capital formation between the last two periods.

Some investigators have chosen to examine the productivity slowdown as a *single* phenomenon beginning in the middle to late 1960s. The argument for a break at the business cycle peak in 1973 seems compelling, however. In addition to the sharp jump in energy prices that occurred, the patterns of productivity growth rates—or slowdowns—in 1965–73 and 1973–78 are quite different. And Norsworthy and Harper have found sharply different patterns of capital formation before and after 1973.[6] We therefore examine the productivity slowdown in two phases: 1965–73 and 1973–78.

By choosing our periods with endpoints that are years of relatively high resource utilization, we avoid the need to make cyclical adjustments in our data. Cyclical adjustment of output and input is an issue closely related to the choice of time periods for analysis. Clearly, productivity growth is slower—and for quarterly measurements it is negative—during economic recession. Measurement of average growth rates in output and input between peaks or over relatively long periods implicitly assumes that the various time periods between the endpoints are comparably affected by negative cyclical influences. But this is clearly not true in the time periods we analyze—the years 1973–78 encompass a far more severe recession in fewer years than did 1965–73. Only insofar as these recession effects are captured in the factors we consider—for example, slower growth of the capital-labor ratio—will they be captured in our analysis. Nadiri and Rosen and Mohr have shown that the adjustment of any factor input to changes in output depends not only on the output change itself, but on the disequilibrium in other inputs.[7] That is, with n inputs, there are n^2 coefficients that describe the adjustment process. Particularly when output changes are accompanied by substantial changes in relative prices, as in 1973–74, the adjustment process may extend beyond the next cyclical peak. At present, the cyclical adjustment issue probably cannot be dealt with in a satisfactory way except in the context of an elaborate model incorporating lagged simultaneous adjustment of inputs. Sufficient evidence exists to suggest that any relatively simple method is inaccurate.

The distribution of the slowdown in labor productivity among major industrial divisions shown in table 2 reveals different patterns in 1965–73 and in 1973–78.[8] In manufacturing, the slowdown was about the same magnitude in each period. Mining productivity began to decline in 1969 when the Federal Coal Mine Health and Safety Act was passed, and productivity has continued to decline in recent years as energy prices have risen and coal has played a larger role relative to petroleum mining. Productivity growth in transportation slowed only slightly in 1965–73, but fell much more in the recent period when energy prices may have retarded an advance in productivity. Productivity growth in communications slowed slightly in 1965–73 and then accelerated in 1973–78. (This industry is clearly not part of the productivity problem.) Utilities showed a reduction in productivity growth in 1965–73 and a virtual halt in 1973–78. Energy prices, oil and gas shortages, and environmental regulations are commonly cited as affecting this industry. Productivity growth accelerated in the trade industries in 1965–73 and fell off sharply in 1973–78. In government enterprises, productivity declined in the base period, grew slightly in 1965–73, and declined again in 1973–78. Agricultural productivity growth slowed in 1973–78.

Measures of output in the remaining three sectors are unreliable, and they are included in the table only to complete the productivity picture in the private business sector. The GNP Data Improvement Project—the Creamer report—urged that output measures for construction be improved because output is now essentially measured as deflated inputs (labor and materials). Construction productivity, as measured, fell in 1965–73 and declined slightly less rapidly in 1973–78, after growing in 1948–65 at near the average rate for the private business sector. A report by the U.S. Department of Commerce found no discernible cause for the

6. Norsworthy and Harper, "Role of Capital Formation."

7. M. Ishag Nadiri and Sherwin Rosen, "Interrelated Factor Demand Functions," *American Economic Review*, vol. 59 (September 1969), pp. 457–71; M. F. Mohr, "A Quarterly Econometric Model of the Long-Term Structure of Production, Factor Demand, and Factor Productivity in 10 U.S. Manufacturing Industries," Staff Paper 9 (Bureau of Labor Statistics, 1978).

8. Output is based on gross product originating in the private domestic business portion of each sector. Output and labor and capital inputs for nonprofit institutions and household workers are excluded because output for those sectors is measured in the national accounts by deflated labor compensation—thus productivity growth is necessarily zero. This deduction is largely from the services sector. We also exclude the imputation for rental value of owner-occupied dwellings both because the labor input of homeowners and their families is not measured, and because final demand categories such as home maintenance and repair and some utilities consumption should properly be considered as intermediate inputs to the imputed output. This exclusion affects the finance, insurance, and real estate sector.

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productivity decline.[9] Within the finance, insurance, and real estate sector, output is measured by labor input in the banking sector, where electronic data processing has made major inroads. Any quality changes resulting from this technological change are therefore not reflected in the output measures for the sector. Measured productivity in that sector fell slightly in 1965–73 after slow growth in 1948–65, and rose again in 1973–78. In the services sector, output is measured by labor input in several constituent industries, and inadequate deflation to account for quality change is commonly cited as a problem. Measured productivity growth increased in 1965–73 and declined in 1973–78.[10]

The U.S. Bureau of Economic Analysis (BEA) does not publish data on capital stocks for federal, state, and local government enterprises. Consequently, we excluded output and labor input for government enterprises from the private business and private nonfarm business sectors. Table 3 shows the effects of the exclusion on the growth of labor productivity in those sectors.

Table 3. Rates of Growth of Labor Productivity for the Private Business and Private Nonfarm Business Sectors, Total and Excluding Government Enterprises, Selected Periods, 1948–78

Annual average, in percent

	Private business		*Private nonfarm business*	
Period	*Total*	*Excluding government enterprises*	*Total*	*Excluding government enterprises*
1948–65	3.20	3.32	2.63	2.77
1965–73	2.25	2.32	1.95	2.02
1973–78	1.12	1.20	1.01	1.09

Sources: Computed by authors using data from the Bureau of Economic Analysis and Bureau of Labor Statistics.

In summary, the pervasiveness of the slowdown suggests that an examination of major economic aggregates may be fruitful. At the same time, growth in labor productivity by industry shows substantial differences between the 1965–73 and 1973–78 periods. An analysis that fails to separate these two periods may miss important causal patterns. We therefore attempt to account for the slowdown in two phases: a slowdown of 1.00 percentage point a year in 1965–73 and a further slowdown of 1.12 percentage points a year in 1973–78.

Framework for Analysis

Our analysis separates growth in labor productivity into growth attributable to changes in the capital-labor ratio, selected factors that alter the effectiveness of measured capital and labor inputs, and residual or otherwise unexplained growth, which may be considered as corresponding to total-factor productivity.

We begin by aggregating the growth rates of labor and capital inputs weighted by their respective shares in output measured at current prices. That is, the weight associated with the labor aggregate, w_L, is the ratio of total labor compensation to nominal output. Similarly, the weight associated with the capital aggregate, w_K, is the ratio of nonlabor payments to nominal output. The measures of output in current and constant prices, labor compensation, nonlabor payments, capital stock, and labor input are based on the national income and product accounts published by the Department of Commerce. The flow of capital services is assumed to be proportional to the net capital stock. The price of capital services is computed as reported by Norsworthy and Harper.[11]

From the definition of total-factor productivity, A, we have

$$A = O \Big/ \sum_{i=1}^{n} w_i X_i,$$

where O is output; w_i is the share of input i in total-factor cost, with $\Sigma w_i = 1$; and X_i is the quantity of input i used in producing O. Using lowercase letters to denote percentage change, we obtain productivity growth, a, from

$$a = o - \sum_{i=1}^{n} w_i x_i.$$

Thus when capital and labor are the only inputs,

$$a = o - w_K k - w_L l.$$

Factors such as composition or quality change can make the effective input of capital or labor differ from the measured input. Designating q_K as the change in factors influencing effective input of capital services and q_L as the change in factors influencing effective input of labor services, we have

$$a = o - w_K k - w_L l - w_K q_K - w_L q_L.$$

To focus on the growth in labor productivity, we rearrange terms to obtain

$$o - l = w_K(k - l) + w_K q_K + w_L q_L + a.$$

The growth in labor productivity thus depends on growth in the capital-labor ratio, factors of composition or quality change, and change in total-factor productivity. If all other factors are unchanged, labor productivity will grow at the same rate as total-factor productivity.

A key assumption that underlies this approach to accounting for growth in labor productivity is that the returns to various types of labor and capital equal their contributions to output—that is, equal their marginal products. This assumption, although questionable for any particular point in time, is widely used in accounting for productivity growth, and is more reasonable as a description of trends over longer periods of time than a single year.

The particular factors whose contribution to labor productivity we analyze can be described briefly. To measure the effect on labor productivity of shifts in labor among sectors, q_{LI}, the growth rates of hours of labor input in the sectors are aggregated using the proportion of total labor compensation in each sector as weights. The effects of changes in the composition of the labor force are computed by Divisia aggregation of various categories of labor input—disaggregated by age, sex, education, occupation, and class of worker. Divisia aggregation sums the growth rates of each category of input, weighting each by its share of total labor input. The index of the change in labor composition, q_{LC}, is then the difference between the growth of the Divisia aggregate and the growth of the directly aggregated (unweighted) labor input. The effect of shifts in the capital stock among asset types, q_{KC}, is measured by aggregating the growth rates of each type of capital asset weighted by each asset's share in total nonlabor payments in the sector. The effect of intersectoral shifts in capital, q_{KI}, is measured by aggregating the growth rates of the capital stock in each sector using the sector's share of total nonlabor payments as a weight. The effect of pollution abatement capital on the growth of the capital stock, k_{PA}, is also a kind of shift effect, and is treated as a deduction from the capital stock.

Each of these factors affecting measured capital and labor inputs is multiplied by the shares of labor and capital in nominal output—w_L and w_K—to compute the associated impacts on growth in labor productivity. The framework for analyzing the effects of changes in various factors contributing to growth in labor productivity thus can be expressed as

$$o - l = w_K(k - l) + w_K q_{KC} + w_K q_{KI} + w_K(-k_{PA}) + w_L q_{LC} + w_L q_{LI} + w_L q_{LH} + a,$$

where

$(k - l)$ = rate of growth of the capital-labor ratio
q_{KC} = effect of changes in the composition of capital
q_{KI} = effect of intersectoral shifts in capital
k_{PA} = rate of growth of pollution abatement capital
q_{LC} = effect of changes in labor force composition
q_{LI} = effect of intersectoral shifts in labor

9. H. Kemble Stokes, Jr., "An Examination of the Productivity Decline in the Construction Industry" (U.S. Department of Commerce, Office of the Chief Economist, March 1979).

10. Interindustry shifts within the service sector account for a major part of measured productivity change.

11. Norsworthy and Harper, "Role of Capital Formation."

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q_{LH} = effect of changes in the ratio of hours worked to hours paid
a = change in total-factor productivity (residual).

The residual or unexplained growth in labor productivity, a, is computed as the difference between observed growth in labor productivity and the contributions of the other effects. Thus it contains the effects of any errors in measurement and of other factors not accounted for in the analysis.

The approach used here to measure sources of growth in labor productivity is similar to the approaches used by Denison and by Frank M. Gollop and Jorgenson in one respect—all depend on a share-weighting scheme to estimate the contributions of various factors to productivity growth.[12] The focus on growth in labor productivity in this paper is an expansion of a similar framework used by Christensen, Cummings, and Jorgenson.[13] Certain differences between our approach and the others should be noted, however. Those relating to measurement of capital and labor input are discussed in the appropriate sections below. Our concept of output measurement is similar to that of most other investigators except Denison. He measures output as net national income at factor cost and thus excludes replacement investment from real output. Consistent with this practice, he also excludes depreciation from the cost of capital, and hence from the share of capital in the nominal value of output. To measure output in this way seems less desirable than to include replacement investment because it is equivalent to assuming that the output that goes to replacing the capital stock could not be diverted elsewhere. Even at the aggregate level, this is untrue—during the 1930s, net investment measured in the national income accounts was negative in at least one year. And at the industry level, negative net investment in a given year is common. Denison's approach reduces the measured effect of capital's contribution to productivity growth because, as noted above, the share of capital is considerably smaller. In addition, the impact of productivity growth on prices cannot be directly observed in Denison's framework because output prices include the full cost of capital. In a period such as 1965–73, when the share of equipment in total investment and hence in the total capital stock was rising, replacement investment was also rising because depreciation occurs faster for equipment than it does for structures. Thus output in the private business sector would rise more rapidly in our accounting framework than in Denison's, other things being equal.

THE CAPITAL STOCK

A number of issues arise in measuring the effects of capital input on the growth of labor productivity. These include how to aggregate the capital stock; whether to use net or gross stocks; whether to include land, inventories, and tenant-occupied housing; and whether to adjust for capacity utilization. These issues are discussed extensively by Norsworthy and Harper.[14] Only the main outline of that argument is summarized here.

Issues in Measurement. Disagreement about the appropriate techniques for aggregation of the capital stock—and, indeed, inputs in general—for productivity analysis has characterized the discussion of production theory in the economics literature.[15] This particular type of index-number problem turns on the validity of direct aggregation of the components of the capital stock, measured in constant prices, as contrasted with translog or Divisia aggregation, which are both based on aggregation of the growth rates of the components weighted by their shares in total capital cost.[16] In terms of the production function, direct aggregation is exact for the Cobb-Douglas specification, which requires strong separability of the inputs being aggregated from other inputs appearing in the production function. Translog aggregation, which is exact for a homothetic translog production function, requires weak separability of the inputs.

We performed econometric tests for each specification. The test for the conditions required for direct aggregation failed by a wide margin for all three sectors, while the test for translog aggregation passed for the private nonfarm and private nonfarm business sectors and failed narrowly for manufacturing.[17] We therefore chose to use translog aggregation in this study.

The choice of net or gross capital stocks of equipment and structures is another issue in the measurement of the growth of the capital stock. For productivity analysis, the issue comes down to whether net or gross capital stock—or, indeed, some other measure—is the better indicator of real capital input. In accounting terms, the difference between the gross and net capital asset measures is the accumulated depreciation on the asset. The method of depreciation and the service life of the capital asset are the determinants of depreciation. There is precedent for using gross capital stock, net capital stock, and a linear combination of the two.[18] Denison uses a linear combination of the net and gross capital stocks to measure real capital input, whereas we use the net stock. Although the service lives of capital assets are difficult to obtain, there is evidence that the net capital stock from the national income accounts understates and the gross stock overstates real capital input.[19] The evidence is incomplete, but Denison's measure may be nearer to real capital input than that used here.

Evidence indicates that the results for 1965–73 are not sensitive to the choice of measures: the net stock of equipment and structures in the private nonfarm business sector grew at an average annual rate of 3.1 percent in 1948–65 and 4.4 percent in 1965–73, while the gross stock grew at rates of 2.7 and 3.9 percent in the respective periods. The changes in the rates of growth therefore differ by only one-tenth of 1 percentage point. The 1973–78 results, however, are sensitive to the choice between net and gross measures.

In simplest terms, the translog aggregation of the capital stock that we use is a method of correcting for aggregation bias because of changes in the composition of the capital stock. The reasoning underlying the use of the technique depends on the assumption that each asset type is used in each sector in such quantity that its marginal product—the value of asset services—is just equal to the price of the services of the asset. The price of those services depends upon the purchase price of the asset, the corporate tax rate, the service life of the asset (or the rate of depreciation), other special tax treatment (such as capital gains or investment tax credit), and the debt-equity structure of corporate liabilities.[20] For example, a shift in the composition of the capital stock from structures to equipment (such as the one that took place from 1965 through 1977) represents an increase in the "quality" of the capital stock because the service life of equipment is shorter than that of structures. Thus the depreciation rate for the aggregate stock is higher, and the cost of capital services is higher. The marginal productivity of the capital stock as a whole is therefore higher, and the flow of capital services in economic terms is greater.

The interindustry mix of the capital stock reflects differences in the rate

12. Denison, *Accounting for United States Economic Growth,* and Frank M. Gollop and Dale W. Jorgenson, "U.S. Productivity Growth by Industry," in John W. Kendrick and Beatrice N. Vaccara, eds., *New Developments in Productivity Measurement* (National Bureau of Economic Research, forthcoming).

13. Laurits R. Christensen, Diane Cummings, and Dale W. Jorgenson, "Economic Growth, 1947–1973: An International Comparison," in Kendrick and Vaccara, eds., *New Developments.*

14. Norsworthy and Harper, "Role of Capital Formation."

15. The disagreement figures prominently in the debate between Edward F. Denison, Dale W. Jorgenson, and Zvi Griliches, which is reproduced in "The Measurement of Productivity," *Survey of Current Business,* vol. 52 (May 1972), pt. 2, pp. 1–111.

16. The term "Törnquist index" is also used. The Divisia index, properly speaking, is a continuous index, and some of the superior mathematical properties claimed for it apply only in the continuous form. See D. W. Jorgenson and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies,* vol. 34 (July 1967), pp. 249–83. The application of the aggregation technique in time-series analysis necessarily involves a discrete approximation to the continuous Divisia form. The particular approximation—more than one is possible—used by Jorgenson and his associates is based on the maintained hypothesis of a translog production or cost function and thus seems best called a translog index. See Laurits R. Christensen, Dale W. Jorgenson, and Lawrence J. Lau, "Transcendental Logarithmic Production Frontiers," *Review of Economics and Statistics,* vol. 55 (February 1973), pp. 28–45.

17. These tests are described in Norsworthy and Harper, "Role of Capital Formation."

18. For gross capital stock see John W. Kendrick, *Postwar Productivity Trends in the United States, 1948–1969,* General Series, 98 (National Bureau of Economic Research, 1973); for net capital stocks see Laurits R. Christensen and Dale W. Jorgenson, "U.S. Real Product and Real Factor Input, 1929–1967," *Review of Income and Wealth,* series 16 (March 1970), pp. 19–50; for a linear combination see Denison, *Accounting for United States Economic Growth.*

19. Charles R. Hulten and Frank C. Wykoff, "Economic Depreciation and the Taxation of Structures in U.S. Manufacturing Industries: An Empirical Analysis," in Dan Usher, ed., *The Measurement of Capital* (National Bureau of Economic Research, forthcoming).

20. See Christensen and Jorgenson, "U.S. Real Capital and Real Factor Input."

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of return on assets among industries. Because we only consider four asset categories, whereas the BEA capital stock information is based on more than twenty classes of equipment alone, there may also be systematic differences in depreciation rates among industries reflecting the different average service lives of the stocks of equipment and structures. Even in the equilibrium model on which this aggregation technique is based, such differences may occur in the average price of capital services across industries reflecting different capital stock composites. Therefore differential rates of growth of the capital stock by industry can lead to changes in the value of the flow of aggregate capital services. As noted below, the asset and industry dimensions of changing capital stock composition can be separated in the translog aggregation process, and reported and analyzed separately.

The translog aggregation procedure makes it possible to isolate the separate contributions of changes in asset type and changes in interindustry composition of the capital stock to the growth of the capital aggregate. We may express the growth rate of the translog index for the capital aggregate, k_T, as

$$k_T = k + q_{KA} + q_{KI},$$

where

k = growth rate of the capital stock directly aggregated
q_{KA} = growth contributed by changes in the asset mix (among equipment, structures, land, and inventories)
q_{KI} = growth contributed by changes in the industry mix of the capital stock.[21]

An additional term, not shown in the expression for k_T above, accounts for the interaction between q_{KI} and q_{KA}. Where it is not shown explicitly, we distributed the value of this term between the values of q_{KI} and q_{KA} in the tables presented below.

Direct and translog aggregation of the capital stock for the private business sector are compared in table 4. The translog aggregate grows more rapidly in all time periods, particularly in 1965–73 when there was a substantial shift to equipment purchases in the manufacturing sector, presumably in response to the investment tax credit. Assets and interindustry shift generally follow the annual growth rates in magnitude. The size of the total capital composition, or quality effect, is important; it provides between 10 and 20 percent of the average annual growth rate in each period. The notion that aggregation effects of this sort can be ignored seems to be refuted effectively. The rates of growth changed and so did their intertemporal pattern: the increase in the rate of capital formation in 1965–73 is greater for the translog aggregate.

In measuring total real capital input for productivity analysis, it is important to include land and inventories as well as measures of equipment and structures.[22] Stocks of inventories measured in current and constant prices and adjusted for price changes are reported by BEA. Corresponding measures of land input are not available from that source. In this paper we adopt the measures used by Kendrick in his estimates of the input of land for the aggregate sectors.[23]

Table 4. Rates of Growth of Capital Stock, by Method of Aggregation, and Contributions to Growth from the Effect of Capital Composition, Private Business Sector, Selected Periods, 1948–78

Annual average, in percent

Period	Method of aggregation		Effect of capital composition			
	Direct	Translog	Total effect	Asset composition	Intersectoral shifts	Interaction between asset composition and shifts
1948–65	2.62	3.14	0.51	0.30	0.34	−0.13
1965–73	3.67	4.48	0.82	0.41	0.51	−0.10
1973–78	2.05	2.31	0.24	0.18	0.10	−0.04

Sources: Computed by authors. Net capital stock series for equipment, structures, and inventories are from the Bureau of Economic Analysis. Data on land are from John W. Kendrick, *The National Wealth of the United States: By Major Sector and Industry*, Report 698 (The Conference Board, 1976), extrapolated for 1975–78 by the authors.

It is important to measure the capital stock that corresponds as closely as possible to the output it produces. In his analysis of productivity growth in the nonfarm business sector, Clark used the capital stock for the private nonfarm sector of the economy and found that some slowdown in labor productivity was attributable to capital formation in 1965–73.[24] In table 5 that capital stock is adjusted to conform to the definition of the private nonfarm business sector by eliminating the capital in nonprofit institutions and including tenant-occupied residential capital.[25] These adjustments increase the acceleration in capital formation between 1948–65 and 1965–73 from 0.74 percentage point to 1.31 percentage points a year, enough to alter sharply Clark's verdict on the role of capital in the 1965–73 slowdown. Inclusion of land and inventories modifies the pattern only slightly. To adjust real capital input—the flow of capital services—for changes in capacity utilization means that part of the corresponding growth (or decline) in output can be traced to the change in capacity utilization. Denison argues extensively and convincingly that this cannot be done.[26] He also argues that adjustment of the entire capital stock by utilization rates in manufacturing is inappropriate because those rates inaccurately reflect utilization rates for other sectors, and for assets other than machinery. A careful reading of Denison's argument—which is too extensive to reproduce or even adequately summarize here—is compelling for us and presumably for Jorgenson, who revised his measurement technique to eliminate adjustment for capacity utilization.[27]

We also make no separate adjustment for technological improvement embodied in the capital stock. Insofar as these advances are reflected in a higher price for the asset, the adjustment for changes in the asset mix will capture the effect. If the improvements are achieved at no cost, the quantity of the asset used in production will be correspondingly adjusted so that the marginal product of the improved asset is equal to its service price, as noted above. Thus in either case the equilibrium nature of the model captures embodied technological change in the quantity or "quality" of the capital stock.

Effects of Capital Spending for Pollution Abatement. The effects of investment in pollution abatement capital (PAK) on productivity growth is assumed to operate only through the capital stock. A reliable estimate of the contribution to the 1965–73 slowdown cannot be made because data for investment in PAK are not available before 1968. The unofficial BEA estimates of PAK investment and net stock are sufficient to fill out the 1965–73 period, and this period can be used as a reasonably good baseline with which to judge the effects of PAK expenditures in 1973–78 on productivity growth.[28] Even the unofficial estimates begin in 1955. We quite arbitrarily projected the estimated investment growth back to 1948 to obtain a baseline for estimating the contributions to the 1965–73 slowdown. The data are poor and the technique mechanical; however, the resulting changes in the rates of growth of the capital stock, shown in table 6, are so small for the earlier periods in all but the manufacturing sector that substantial changes in technique would make little difference. The effects on the growth of labor productivity in the private business, private nonfarm business, and manufacturing sectors are estimated by weighting the capital devoted to pollution abatement by the share of capital in total output in the sectors.

21. Only three industry sectors are recognized in the capital stock and investment data available from the U.S. Bureau of Economic Analysis: manufacturing, farm, and nonfarm nonmanufacturing. Because the definition of asset is a general one, finer detail for each industry typically leads to a reallocation of capital "quality" change—as the sum of the q terms above is often called—from asset to industry. See Gollop and Jorgenson, "U.S. Productivity Growth."

22. See Denison, *Accounting for United States Economic Growth;* Gollop and Jorgenson, "U.S. Productivity Growth"; and Kendrick, *Postwar Productivity.*

23. John W. Kendrick, *The National Wealth of the United States: By Major Sector and Industry*, Report 698 (The Conference Board, 1976).

24. Clark, "Capital Formation," p. 974.

25. Aggregates in table 5 are based on direct aggregation of capital stocks.

26. Edward F. Denison, "Some Major Issues in Productivity Analysis: An Examination of Estimates by Jorgenson and Griliches," *Survey of Current Business,* vol. 49 (May 1969), pt. 2, pp. 1–29.

27. Ibid., and Gollop and Jorgenson, "U.S. Productivity Growth."

28. A more complete discussion of the quality of PAK data and their meaning is found in John E. Cremeans, "Capital Expenditures by Business for Air and Water Pollution Abatement, 1973 and Planned 1974," *Survey of Current Business,* vol. 54 (July 1974), pp. 58–64; and his "Conceptual and Statistical Issues in Developing Environmental Measures—Recent U.S. Experience," *Review of Income and Wealth,* series 23 (June 1977), pp. 97–115.

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Table 5. Reconciliation of Nonresidential Equipment and Structures to Business Capital, Private Nonfarm Business Sector, Selected Years, 1948–78[a]

Item	Net stock (billions of 1972 dollars)				Rate of growth (percent)		
	1948	1965	1973	1978	1948–65	1965–73	1973–78
Nonresidential equipment and structures	304.41	597.08	867.47	991.86	4.05	4.79	2.72
Minus: Capital of nonprofit institutions	25.23	64.67	88.58	92.37	5.69	4.02	0.84
Equals: Nonresidential business equipment and structures	279.18	532.41	778.88	899.50	3.88	4.88	2.92
Plus: Tenant-occupied residential capital	128.42	156.73	197.46	202.00	1.19	2.93	0.46
Equals: Business equipment and structures	407.60	689.14	976.34	1,101.49	3.14	4.45	2.44
Plus: Land and inventories	158.11	261.09	358.47	388.25	3.03	4.05	1.64
Equals: Business capital	565.71	950.23	1,334.81	1,489.75	3.10	4.34	2.23

Source: Computed by authors using data from the Bureau of Economic Analysis. Figures are rounded.
a. The aggregates are based on direct aggregation of capital stocks.

For the last period, the growth of the capital stock is affected noticeably by the adjustment for pollution abatement. For the periods before 1973, the table demonstrates that PAK expenditures had a minimal effect on the capital aggregates. The effects in particular sectors were obviously greater than what is shown in these aggregate data. Denison examines the proposition from a broader perspective and still finds no major impact, although his is an aggregate perspective also.[29]

ADJUSTMENT FOR THE COMPOSITION OF THE LABOR FORCE AND FOR INTERINDUSTRY SHIFT

We adapt the method used by Gollop and Jorgenson to analyze the effects of the composition of the labor force and interindustry shifts.[30] Our procedure also follows Denison's analysis closely.[31] Denison does not account for different occupation groups nor is he always able to weight all the separate characteristics by their specific relative wage as we do; however, this is because of a lack of data rather than a difference in approach.

The basic technique for translog aggregation of the various components of the labor force is the same as that for aggregation of the capital stock: each category of labor input is assumed to be paid the value of its marginal product in each year. Thus relative increases in the proportion of higher paid labor categories to total labor input are taken to represent increases in effective input. This assumption underlies the adjustment by Denison as well as by Gollop and Jorgenson for changes in effective labor input.

To account for changes in the composition of labor input, the total hours for each sector analyzed here—the private business, private nonfarm business, and manufacturing sectors—are disaggregated according to sex, age, education, occupation, and employment class of worker (self-employed or employee) for each year from 1948 to 1978. Total compensation for each sector was disaggregated in the same manner. In all, there are 1,600 disaggregations for each sector (two groups for sex, two for worker employment class, five for education, eight for age, and ten for occupation).

The interindustry disaggregation was based on the industry detail from the national income and product accounts: the private business sector is composed of sixty-two industries; the private nonfarm business sector, sixty-one industries; and the manufacturing sector, twenty-one industries. The raw data for the disaggregation was compiled from records of the U.S. Bureau of the Census, special labor force reports published by the BLS, and for the last years, from tapes from the Current Population Survey.[32]

The growth rate in the adjustment for labor composition, q_{LC}, is defined as the growth in labor services adjusted for all categories of labor, h, less the growth in unadjusted hours worked, l:

$$q_{LC} = h - l,$$

where labor services is a function of the various categories of labor input, L_i:

$$H = f(L_1, L_2, \ldots, L_N).$$

Assuming f is a linear homogenous logarithmic function, the growth in labor services is the derivative with respect to time:

$$h = \sum_{i=1}^{n} v_i l_i,$$

where

$$v_i = \frac{df}{dL} \quad \text{and} \quad \sum_{i=1}^{n} v_i = 1.$$

We further decompose labor services into q_{LC} and l. Adding and then subtracting the growth rate in unadjusted hours from the right-hand side yields

$$h = \sum_{i=1}^{n} v_i(l_i - l) + l.$$

The difference $(l_i - l)$ is interpreted as the growth rate of the proportion of total hours worked by the ith category of workers. The growth rate of labor services can thus be expressed as the sum of the rates of changes in q_{LC} and l. That is,

$$h = q_{LC} + l,$$

Table 6. Rates of Growth of the Capital Stock, Total and Excluding Pollution Abatement Capital, by Sector, Selected Periods, 1948–78[a]
Annual average, in percent

Sector	1948–65		1965–73		1973–78	
	Total	Excluding pollution abatement capital	Total	Excluding pollution abatement capital	Total	Excluding pollution abatement capital
Private business	3.14	3.11	4.48	4.37	2.31	2.05
Private nonfarm business	3.24	3.21	4.59	4.47	2.37	2.09
Manufacturing	2.93	2.86	3.93	3.64	2.16	1.47

Source: Computed by authors using data from the Bureau of Economic Analysis.
a. The aggregates are based on direct aggregation of capital stocks.

29. Denison, "Effects of Selected Changes," p. 42. The effects of pollution abatement and health and safety regulations are analyzed by Denison in a different manner. He concludes that by 1975 the annual impact of these activities as well as private expenditures for crime prevention may have contributed as much as 0.26 percentage point a year to the slowdown measured from 1969 to 1975, reaching 0.47 percentage point from 1973 to 1975.

30. Gollop and Jorgenson, "U.S. Productivity Growth."

31. Denison, *Accounting for United States Economic Growth*, pp. 30–50, 219–59. For a comparison of the analyses by Denison, Gollop and Jorgenson, and Kendrick, see Kent Kunze, "Evaluation of Labor Force Composition Adjustment," in *Measurement and Interpretation of Productivity* (National Academy of Sciences, forthcoming).

32. The disaggregation of the hours and compensation was resolved by use of a multiproportional matrix model. The annual hours and compensation are controlled at the industry level for employees, with only the hours and compensation for the self-employed and unpaid family workers adjusted according to the March Current Population Survey.

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where

$$q_{LC} = \sum_{i=1}^{n} v_i(l_i - l).$$

The ratio of hourly compensation between categories is assumed to be equal to the ratio of marginal products for each category of labor.

Two sets of indexes are computed for each of the major sectors: one for changes in sex, age, education, occupation, and class of worker; the other for changes in labor input among industries, q_{LI}.

Separation of the industry adjustment from the adjustment for labor composition assumes independence between them. This assumption was investigated by calculating a measure of labor composition using industry as one of the characteristics. If independence exists, no difference occurs between this measure and the sum of the two measures we have used, q_{LI} and q_{LC}. There was virtually no difference for the private business and private nonfarm business sectors in either the 1948–65 or the 1965–73 periods.[33] This was not the case in the manufacturing sector, where a significant interaction seemed to occur between q_{LC} and q_{LI}. For all sectors, the measured interaction term was added to the adjustment for labor composition.

Table 7 indicates the annual growth rates for adjusted labor composition and adjusted interindustry shifts as computed above. (These growth rates have not been weighted by labor's share, w_L.) The contribution to labor productivity provided by the changing composition of the labor force decreased by more than 50 percent for all sectors from the 1948–65 to 1965–73 period and increased in 1973–78. The contribution of interindustry shift, on the other hand, increased significantly from the first to second period for the private business and private nonfarm business sectors, then decreased substantially in 1973–78. Interindustry shift has had little effect in the manufacturing sector.

To obtain a better understanding of the cause for the changes in labor composition, we also examined the separate direct effects of age, sex, education, occupation, and class of worker, as shown in table 8. These growth rates show the composition adjustment separately for the specific characteristics. The effects are not simply additive to q_{LC} because they are not independent; however, they do show which characteristics exhibited the largest effect on the change in the labor composition and the direction of the effects.

The growth rates presented in table 8 show that age was the major factor contributing to the downward adjustment from labor composition for the first period of slowdown. In all three sectors this characteristic went from a positive to a negative annual growth rate, corresponding directly to the large increase of young workers as the postwar baby-boom cohort entered the labor market. For the private nonfarm and private business sectors the age factor reversed itself in the third period, but the increase in female entrants to the labor force seemed to compensate for this reversal. Especially rapid entry of females took place in nonfarm-nonmanufacturing industries, an area that has historically shown a smaller increase in productivity. This development did not affect the manufacturing sector. However, the age factor did continue to depress the composition of the labor force in manufacturing for the third period. Educational attainment increased and added to effective labor input in the 1965–73 and 1973–78 periods for all sectors. Education and occupation are highly interrelated factors, so that adjusting for education alone also captures a significant amount of the contribution from the changing occupation mix.

Table 7. Rates of Growth of Adjustments to Total Hours for Changes in Labor Composition and for Interindustry Shifts, by Sector, Selected Periods, 1948–78
Annual average, in percent

Period	*Private business*		*Private nonfarm business*		*Manufacturing*	
	Labor composition	*Interindustry shifts*	*Labor composition*	*Interindustry shifts*	*Labor composition*	*Interindustry shifts*
1948–65	0.17	0.23	0.18	−0.02	0.20	−0.03
1965–73	0.08	0.30	0.03	0.18	0.07	−0.03
1973–78	0.14	−0.11	0.06	−0.12	0.11	0.07

Source: Computed by authors as explained in the text, using the method described in Frank M. Gollop and Dale W. Jorgenson, "U.S. Productivity Growth by Industry, 1947–1973," in John W. Kendrick and Beatrice N. Vaccara, eds., *New Developments in Productivity Measurement* (National Bureau of Economic Research, forthcoming). The basic data are from the U.S. Bureau of the Census and the Bureau of Labor Statistics.

Table 8. Rates of Growth of Direct Effects of Labor Characteristics on Labor Composition, by Sector, Selected Periods, 1948–78
Annual average, in percent

Sector and period	*Sex*	*Employment class of worker*	*Age*	*Education*	*Occupation*
Private business					
1948–65	−0.11	−0.02	0.08	0.46	0.31
1965–73	−0.07	−0.00	−0.27	0.95	0.28
1973–78	−0.23	−0.13[a]	−0.23	1.05	0.25
Private nonfarm business					
1948–65	−0.06	−0.05	0.04	0.33	0.06
1965–73	−0.07	−0.05	−0.30	0.85	0.11
1973–78	−0.23	0.02[a]	−0.08	1.00	0.24
Manufacturing					
1948–65	−0.04	−0.03	0.17	0.49	0.30
1965–73	−0.08	0.00	−0.16	0.81	0.36
1973–78	−0.06	0.02[a]	−0.17	0.75	0.52

Source: Computed by authors as described in the text, using data from the Bureau of the Census and the Bureau of Labor Statistics.
a. Calculated for the 1973–76 period.

HOURS WORKED VERSUS HOURS PAID

Labor productivity is generally measured using hours paid as the labor input measure. The data are taken from the current employment statistics (CES) program's survey of nonagricultural establishments, which has far greater coverage than any currently available survey of hours worked.[34] A 1976 report by the BLS found that no available survey provides data on hours worked that are sufficiently accurate to serve as a basis for quarterly or annual measures of labor productivity.[35]

Insofar as hours paid exceed hours worked, the level of labor productivity will therefore be understated. Measured growth in labor productivity will be affected only if the ratio of hours worked to hours paid changes through time; the measured slowdown in productivity growth will be affected only if the rate of change of that ratio is altered. Recent work by Stafford and Duncan,[36] based on quite small samples, shows that the divergence between hours worked and hours paid accounts for as much as one-third of the productivity slowdown. This suggests that it is worthwhile to use the best available data to attempt to quantify the effect.

The BLS report made rough estimates of hours worked from 1952 to 1965, based on exclusion of leave from the CES data on hours paid, and from 1966 to 1975, based on the Employer Expenditures for Employee Compensation survey.[37] From these data we estimated average annual rates of change in the ratio of hours worked to hours paid for 1952–65, 1965–73, and 1973–75 in private business, private nonfarm business, and manufacturing. The results, shown in table 9, are not striking. There is a small, persistent but variable decline in the ratio of hours worked to hours paid in each sector, except for manufacturing in the last period. The effects on growth of labor productivity were estimated by assuming that the average annual growth rates for 1952–65 and 1973–75 characterized the periods 1948–65 and 1973–78—a rather weak technique. The resulting values were weighted by the share of labor in total output in the three sectors.

33. The data have not been developed at this time to measure the interaction for 1977 and years following. To use only the 1973–76 period would be inappropriate.

34. The ideal target concept is hours actually worked. In this paper we use the term to denote hours at the workplace, a concept that excludes paid leave (vacation, holiday, and sick leave).

35. Bureau of Labor Statistics, "Report of the BLS Task Force on Hours Worked" (BLS, March 1976). Modification of the survey to include the collection of data on hours worked is now planned.

36. Frank P. Stafford and G. I. Duncan, "The Use of Time and Technology by Households in the United States," in Ronald G. Ehrenberg, Orley Ashenfelter, and Ronald L. Oaxaca, *Research in Labor Economics*, vol. 3 (JAI Press, forthcoming).

37. The Employer Expenditures for Employee Compensation survey covered 6,000 establishments, primarily large ones, from 1966 to 1974. While the data are not comparable to the time-use diaries cited by Stafford and Duncan, the sample size and frequency is considerably larger. See ibid.

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Table 9. Rates of Change in the Ratio of Hours Worked to Hours Paid, by Sector, Selected Periods, 1952–75

Annual average, in percent

Sector	1952–65	1965–73	1973–75
Private business	−0.08	−0.22	−0.14
Private nonfarm business	−0.06	−0.21	−0.12
Manufacturing	−0.06	−0.40	0.03

Sources: Computed by authors from data in Bureau of Labor Statistics, "Report of the BLS Task Force on Hours Worked" (BLS, March 1976).

ENERGY AND PRODUCTIVITY

We can make only a limited appraisal of the impact of higher energy prices on the growth of labor productivity in the private business and private nonfarm business sectors. Data on energy use are not available by sector, but rather by the following categories: industrial, commercial, transportation, and residential. These categories have not been mapped into the major economic sectors with sufficient accuracy to justify their inclusion in the productivity accounting framework. In addition, our framework uses a concept of output based on gross product originating, so that flows of intermediate products—including energy—are excluded, although value-added is included in the energy-producing sectors.

It is possible to appraise the effects of energy price increases based on the energy share in output in the major sectors, as Denison has done. However, his procedure implicitly assumes that the elasticity of substitution between energy and other factors is one, and strong evidence exists to the contrary, at least for the manufacturing sector. Berndt and Wood and Hudson and Jorgenson find complementarity between energy and capital in U.S. manufacturing;[38] Griffin and Gregory, using cross-section and time-series data for several countries, find substitution.[39] Our own recent investigation relied on a dynamic adjustment model of the manufacturing sector in an attempt to remove the short-term complementary use of capital and energy suggested by Griffin and Gregory as a major cause of the Berndt and Wood findings. We found stronger complementarity in the long-run than in the short-run version of the model.[40]

Using this model of the manufacturing sector, we undertook a simulation exercise for the 1973–78 period to assess the effects of increases in energy prices on the growth of labor productivity as these effects operate through changing the capital-labor ratio. Whatever actual effect energy prices have had on this ratio is included in the total estimated effect of capital formation on productivity. Here we suggest how much of that may be attributable to higher energy prices. The simulation assumes that energy prices rose at the same rate as the implicit price deflator for manufacturing rather than at the 22.3 percent rate that actually occurred. On this basis, the model suggests that the capital-labor ratio would have increased at an annual rate of about 2.3 percent instead of 1.7 percent. Thus labor productivity would have risen about 0.18 percentage point a year faster in manufacturing during 1973–78 if the relative price of energy had not changed. Hudson and Jorgenson also find a large reduction in investment for the 1972–76 period resulting from higher energy prices. Their study, which uses a more complete model of the economy, includes complementarity between energy and capital.[41]

RESEARCH AND DEVELOPMENT

A number of investigators have argued that research and development expenditures have important effects on productivity growth. Kendrick is perhaps the strongest proponent of this view and his quantitative estimate of the effects of R&D is the largest.[42] Kendrick regresses the total-factor productivity (TFP) residual on a measure of the stock of accumulated knowledge. The quantitative estimates from this procedure depend upon how one quantifies knowledge and on how one defines TFP: if, as in Kendrick's case, it is defined as the ratio of output to the sum of share-weighted factor inputs, the effect will be relatively large; if, as in our analysis, factor-augmenting effects are removed from TFP, the effect will be smaller. In either case, the regression will attribute to R&D the effects of all unaccounted factors insofar as they have similar intertemporal patterns. On the other hand, to the extent that the effects of R&D can be seen in capital or labor or change the capital-labor ratio, some of the effect may be missed by attributing it to other factors in the analysis. It is not clear what approach, if any, can be relied upon to capture all the effects. Thus, although there seems to be a consensus that the decline in R&D expenditures is partially responsible for the slowdown in productivity growth, we found no satisfactory way to include the effect in our analysis.

Accounting for the Slowdown

As the preceding discussion indicates, some hypotheses about the causes of the productivity slowdown defy quantification. In table 10 we present the estimated effects of those factors that could be incorporated into this analysis for the private business, private nonfarm business, and manufacturing sectors. All three sectors show significant declines in labor productivity for both slowdown periods; the total effect of those slowdowns is smallest in manufacturing and greatest in private business, where the farm-to-nonfarm shifts of labor and capital contributed substantially to growth before 1965. In private business and private nonfarm business, total-factor productivity growth, the "other factors" category in the table, declines very little between 1965–73 and 1973–78.

The changes in the growth rates from table 10 are presented in table 11 as a way of detailing the contributions to the productivity slowdown from the various factors analyzed. One conclusion is immediate—two slowdowns occurred with two different patterns of contributing causes: the 1965–73 slowdown is largely unexplained by factors quantified in this analysis; the 1973–78 slowdown is largely accounted for by the relative weakness in capital formation.

In the private business sector, the broadest aggregate, the total effects from capital formation augmented productivity growth in the first slowdown period; the effect of changes in capital composition more than compensated for the slight impacts of expenditures for pollution abatement and the capital-labor ratio. The latter effect was due entirely to slower growth in the capital-labor ratio in the farm sector, where the growth of the capital-labor ratio slowed largely because the rapid migration of labor from the farm sector had ended. Labor effects in the first slowdown period in the private business sector were small, although they contributed somewhat to the slowdown. Favorable interindustry shift effects were more than offset by a decline in the ratio of hours worked to hours paid and changes in the composition of the labor force. The dominant effect in the first slowdown period comes from other factors, which account for more than 90 percent of the total decline in the growth of labor productivity.

Different factors account for the productivity slowdown in the second period. Capital effects account for 0.79 percentage point out of a total decline of 1.12 percentage points. In this period the decline in growth of the capital-labor ratio contributes the largest effect, but changes in the asset and interindustry composition also add to the slowdown, and capital spending for pollution abatement makes a small negative contribution as well. Labor effects contribute somewhat more to the 1973–78 slowdown than in the earlier period, but the pattern is quite different. Changes in the composition of the labor force resulting largely from increased

38. Ernst R. Berndt and David O. Wood, "Technology, Prices, and the Derived Demand for Energy," *Review of Economics and Statistics*, vol. 57 (August 1975), pp. 259–68; Hudson and Jorgenson, "Energy Prices."

39. James M. Griffin and Paul R. Gregory, "An Intercountry Translog Model of Energy Substitution Responses," *American Economic Review*, vol. 66 (December 1976), pp. 845–57.

40. J. R. Norsworthy and Michael J. Harper, "Productivity Growth in Manufacturing in the 1980's: Labor, Capital, and Energy, in American Statistical Association, *Proceedings of the Business and Economic Statistics Section* (Washington, D.C.: ASA, forthcoming). The study was based on a four-factor model (capital, labor, energy, and intermediate materials) of manufacturing using energy data from Bureau of the Census, *Census of Manufactures*, for 1958, 1963, 1967, 1972, and 1977; and Bureau of the Census, *Annual Survey of Manufactures*, for intermediate years.

41. Hudson and Jorgenson, "Energy Prices," p. 1.33.

42. John W. Kendrick, *The Formation and Stocks of Total Capital*, General Series, 100 (National Bureau of Economic Research, 1976). Kendrick represents the stock of accumulated knowledge by the capitalized value of research and development expenditures.

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Table 10. Rates of Growth of Labor Productivity and of Capital and Labor Effects on Productivity, by Sector, Selected Periods, 1948–78
Annual average, in percent

Item	Private business			Private nonfarm business			Manufacturing		
	1948–65	1965–73	1973–78	1948–65	1965–73	1973–78	1948–65	1965–73	1973–78
Labor productivity growth	3.32	2.32	1.20	2.77	2.02	1.09	3.13	2.47	1.70
Capital effect									
Capital-labor ratio	0.76	0.75	0.21	0.68	0.84	0.20	0.54	0.72	0.44
Asset composition	0.06	0.10	0.05	0.05	0.08	0.04	0.03	0.05	0.03
Intersectoral shifts	0.12	0.17	0.03	0.00	0.00	0.00	n.a.	n.a.	n.a.
Pollution abatement capital	0.00[a]	−0.03[a]	−0.09	−0.01[a]	−0.04[a]	−0.09	−0.03[a]	−0.09[a]	−0.19
Total	0.94	0.99	0.20	0.72	0.88	0.15	0.54	0.68	0.28
Labor effect									
Labor force composition	0.12	0.06	0.10	0.12	0.01	0.04	0.14	0.05	0.08
Interindustry shifts	0.15	0.20	−0.07	−0.02	0.12	−0.08	−0.02	−0.02	0.05
Ratio of hours worked to hours paid	−0.05	−0.14	−0.09	−0.04	−0.14	−0.08	−0.04	−0.07	0.02
Total	0.22	0.12	−0.06	0.06	−0.01	−0.12	0.08	−0.04	0.15
Effect of other factors	2.16	1.21	1.06	1.99	1.15	1.06	2.51	1.83	1.27

Sources: Computed by authors as explained in the text, using data from the Bureau of Economic Analysis and the Bureau of Labor Statistics.
a. As indicated in the text, estimates for these periods are based on partial data.
n.a. Not available.

education have a positive effect on productivity growth, as does the ratio of hours worked to hours paid (though, again, the data underlying this latter estimate are weak). Interindustry shifts of the labor force have a strong negative influence. Other factors play a much smaller role than in the 1965–73 slowdown; only about 13 percent of the 1973–78 slowdown in the private business sector is not accounted for by the measured capital and labor effects.

In the private nonfarm business sector the pattern in the first slowdown period is generally similar to that for the private business sector, although capital effects are even more favorable to productivity growth because the capital-labor ratio grows more rapidly in 1965–73 than in 1948–65. The pattern of labor effects is quite similar to that in private business, although the net impact is slightly smaller. And other factors are again the dominant slowdown factor. Indeed, after adjusting for capital and labor effects, the contribution to the slowdown of other factors is somewhat larger than the slowdown in labor productivity itself.

In the second period, capital effects contribute nearly 80 percent of the observed slowdown in labor productivity. As in the private business sector, the dominant impact comes from slower growth in the capital-labor ratio. Capital spending for pollution abatement and changes in the asset mix each have a small effect. Labor effects contribute somewhat, with a downward push on productivity from interindustry shifts more than offsetting small contributions in the other direction from the composition of the labor force and changes in hours worked. As in the private business sector, the measured capital and labor effects account for most of the 1973–78 slowdown in productivity growth in the private nonfarm business sector.

The productivity slowdown pattern in the manufacturing sector is similar to that for private nonfarm business in 1965–73: capital effects contribute to faster productivity growth, and total labor effects reduce it. During this period, the acceleration of the capital-labor ratio increased productivity growth by about 0.2 percentage point a year, but was partially offset by expenditures for pollution abatement capital and a slight asset effect. Labor effects made a small contribution to the slowdown, largely through changes in the composition of the labor force. Other factors not accounted for in the analysis dominate the productivity decline in manufacturing in the first slowdown period.

In the 1973–78 period, some differences emerge between the manufacturing sector and the private nonfarm business sector. The productivity slowdown is somewhat smaller in manufacturing. Capital effects, dominated by slower growth in the capital-labor ratio, are more strongly influenced by expenditures for pollution abatement capital. The effect,

Table 11. Contributions to the Slowdown in the Growth of Labor Productivity, by Sector, 1965–78[a]
Annual average, in percentage points

Item	Private business			Private nonfarm business			Manufacturing		
	1965–73 slowdown	1973–78 slowdown	Total	1965–73 slowdown	1973–78 slowdown	Total	1965–73 slowdown	1973–78 slowdown	Total
Change in labor productivity growth	−1.00	−1.12	−2.12	−0.75	−0.93	−1.68	−0.66	−0.77	−1.43
Contribution from capital effect									
Capital-labor ratio	−0.01	−0.54	−0.55	0.16	−0.64	−0.48	0.18	−0.28	−0.10
Asset composition	0.04	−0.05	−0.01	0.03	−0.04	−0.01	0.02	−0.02	0.00
Intersectoral shifts	0.05	−0.14	−0.09	0.00	0.00	0.00	n.a.	n.a.	n.a.
Pollution abatement capital	−0.03	−0.06	−0.09	−0.03	−0.05	−0.08	−0.06	−0.10	−0.16
Total	0.05	−0.79	−0.74	0.16	−0.73	−0.57	0.14	−0.40	−0.26
Contribution from labor effect									
Labor force composition	−0.06	0.04	−0.02	−0.11	0.03	−0.08	−0.09	0.03	−0.06
Interindustry shifts	0.05	−0.27	−0.22	0.14	−0.20	−0.06	0.00	0.07	0.07
Ratio of hours worked to hours paid	−0.09	0.05	−0.04	−0.10	0.06	−0.04	−0.03	0.09	0.06
Total	−0.10	−0.18	−0.28	−0.07	−0.11	−0.18	−0.12	0.19	0.07
Contribution from effect of other factors	−0.95	−0.15	−1.10	−0.84	−0.09	−0.93	−0.68	−0.56	−1.24

Source: Derived from the results of table 10.
a. The 1965–73 slowdown is measured relative to the 1948–65 base period; the 1973–78 slowdown, relative to the 1965–73 slowdown.
n.a. Not available.

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however, is still small in manufacturing, where a major impact of environmental regulations would be expected to be felt. Capital effects, however, explain only about half of the 1973–78 slowdown in manufacturing, a much smaller proportion than in private nonfarm business. The labor effects augmented productivity growth. Thus, in the second period, other factors play a larger role in the slowdown of the manufacturing sector than in the other sectors.

The slowdown patterns for the nonfarm nonmanufacturing sector that are implied by the nonfarm and manufacturing results in tables 10 and 11 are summarized in table 12. The capital effects were determined by weighting the capital effects in each sector by the relative size of their capital stock. A similar procedure was used for labor productivity and labor effects based on the nonfarm nonmanufacturing share in the hours of private nonfarm business labor.[43]

In this sector, productivity again slows noticeably in both periods. In the first period, total capital effects work against the slowdown, while total labor effects contribute to it and are noticeably larger than those for all nonfarm business. As in the private nonfarm business sector, other factors are the primary source of the decline in productivity growth. Almost all the second slowdown is explained by capital and labor effects that parallel those in total private nonfarm business, so that other factors play a minor role.

For any of the major sectors analyzed here, to view the productivity slowdown as a single phenomenon beginning in the mid-1960s would distort the temporal pattern of contributions to it, and would likely lead to poor policy prescription. From the evidence of the recent period, the unexplained decline in multifactor productivity growth is largely behind us, while the problem of capital formation is current. It also appears that the changing composition of the labor force has contributed somewhat less to the slowdown in either period than some other estimates have suggested and, correspondingly, may offer somewhat less hope for reversal in the future.

Factors Affecting Capital Formation

Because slower capital formation appears to have been a major cause of the slowdown in labor productivity in the 1973–78 period, it is important to understand why. Table 13 attempts to shed light on this question.[44]

The acceleration of the capital-labor ratio in 1965–73 may be explained by price-induced substitution of capital for labor. The price of labor grew about 2 percentage points a year faster than the price of capital services in 1948–65, more than 4 points faster in 1965–73, and 1 point faster in 1973–78. These differences measure the relative price change of labor as compared to capital: the price incentive to substitute capital for labor was thus about twice as strong in 1965–73 as it was in the earliest period, and about four times as great as in 1973–78. A factor holding down the relative price of capital services in 1965–73 was the investment tax credit for equipment that went into effect in the mid-1960s.

Table 12. Capital and Labor Effects on the Growth of Labor Productivity, Private Nonfarm Nonmanufacturing Sector, Selected Periods, 1948–78

Annual average

Item and period	*Total labor productivity*	*Capital effect*	*Labor effect*	*Effect of other factors*
Rate of growth (percent)				
1948–65	2.57	0.78	0.11	1.68
1965–73	1.78	0.95	−0.10	0.93
1973–78	0.80	0.11	−0.22	0.91
Contribution to slowdown (percentage points)				
1965–73 slowdown	−0.79	0.17	−0.21	−0.75
1973–78 slowdown	−0.98	−0.84	−0.12	−0.02
Total	−1.77	−0.67	−0.33	−0.77

Source: Data are inferred from tables 10 and 11 as described in the text.

Table 13. Rates of Growth of Input Prices, Private Nonfarm Business Sector, Selected Periods, 1948–78

Annual average, in percent

Period	*Price of capital services*	*Labor compensation per hour*	*Price of energy input*[a]
1948–65	2.84	4.60	−0.73
1965–73	2.20	6.58	4.73
1973–78	7.95	8.98	22.29

Source: J. R. Norsworthy and Michael J. Harper, "The Role of Capital Formation in the Recent Productivity Growth Slowdown," Working Paper 87, (Bureau of Labor Statistics, January 1979).

a. The energy price series is for 1954–65, 1965–73, and 1973–77. It is based on the ratio of total cost of purchased fuels in manufacturing to a translog index of electricity, coal, coke, fuel oil, and natural gas quantities from Bureau of the Census, *Census of Manufactures*. The wholesale price index was used to interpolate some price components between Census benchmarks.

The relative price explanation for the acceleration in the capital-labor ratio in the 1965–73 period also explains the deceleration in 1973–78, when the relative price change was so small. The rapid rise in energy prices that took place in late 1973 and early 1974 may be another important factor contributing to the slowdown in this last period. If capital and energy are complements, the rise in energy prices would have retarded capital formation.[45]

The weak productivity growth of recent years has corresponded with a rapid and continued rise in employment from the trough of the 1973–75 recession through early 1979. This phenomenon, which has been widely observed and described as puzzling, is consistent with the much closer movements in the prices of capital and labor and the complementarity between capital and energy. Under these conditions, increases in output would be achieved with relatively greater expansion of labor input and less expansion of capital (and hence energy) than under the price conditions that prevailed since 1948 in general, and in the 1965–73 period in particular. This tentative explanation is consistent with findings by Hudson and Jorgenson for the 1973–76 period.[46]

The main conclusions of our investigation of the slowdown in the growth of labor productivity can be summarized briefly.

There are two distinct phases to the slowdown in the growth of labor productivity: 1965–73 and 1973–78. Differences are apparent both in the pattern of productivity growth among industries and in the factors contributing to the decline.

The 1965–73 slowdown is largely unexplained by the factors we have considered. Capital formation was not a cause; changes in the composition of the labor force played a relatively minor role. Although R&D expenditures slowed during this period and may well have contributed to the productivity slowdown, we devised no satisfactory means to take this factor into account. Intersectoral shifts of capital and labor did not contribute.

The 1973–78 slowdown is dominated by the effects of reduced capital formation. Some effect is also attributable to interindustry shifts in labor and capital. The sharp rise in energy prices may show up in a framework such as ours through its impact on capital formation and may help explain the relative weakness in capital formation in recent years.

43. Direct computation would have been preferable. However, the difference in patterns between the nonfarm business and manufacturing sectors did not emerge until it was too late to compute these effects directly. Although the total effects for capital, labor, and other factors reported in table 12 would change very little when directly computed, detailed effects of changes in factor composition and interindustry shifts would be revealed.

44. Data for the private nonfarm business sector are shown because the slowdown in capital formation in agriculture began before 1973–78, and the relative rise of wages in the agriculture sector further obscures the relative price movements that prevailed in private nonfarm business.

45. There are, of course, other dimensions to the problem, and therefore to a satisfactory explanation for it. For example, an accelerator model of capital accumulation is examined in Peter K. Clark, "Investment in the 1970s: Theory, Performance, and Prediction," *BPEA, 1:1979*, pp. 73–113. The slowdown in output growth of more than 1 percentage point a year between 1965–73 and 1973–78 would also explain part of the slowdown in capital formation in the latter period.

46. Hudson and Jorgenson, "Energy Prices."

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Part III. Productivity Trends in Industries and the Federal Government

This section includes a brief historical introduction to productivity measurement in industries and in the Federal Government. Methods, sources, and uses of the measures are discussed and an excerpt from the most recently published compilation of industry productivity measures serves as an example of recent results.

One essay analyzes the difficulties in measuring productivity in service industries and explores their solution. The complexities of measuring output per hour in government are also discussed. The articles on labor productivity trends in several industries examine the factors underlying productivity change over time.

Background

Studies of output per employee hour in individual industries have long been a part of the BLS program. A study of 60 manufacturing industries in 1898, prompted by congressional concern that human labor was being displaced by machinery, was presented in the report *Hand and Machine Labor;* this provided striking evidence of the savings in labor resulting from mechanization in the last half of the 19th century. The impact of productivity advance upon employment remained an important focus of BLS throughout the 1920's and 1930's. Also during this period, the Bureau began the preparation and publication of industry indexes of output per employee hour, which were based on available production data from the periodic Census of Manufactures and employment statistics collected by BLS.

In 1940, Congress authorized the Bureau of Labor Statistics to undertake continuing studies of productivity and technological changes. The Bureau extended earlier indexes of output per employee hour developed by the National Research Project of the Works Progress Administration, and published measures for selected industries. This work, however, was reduced in volume during World War II, owing to the lack of meaningful production and employee hour data for many manufacturing industries.

The advent of World War II also caused a change in the emphasis of the program from problems of unemployment to concern with the most efficient utilization of scarce labor resources. BLS undertook a number of studies of labor requirements for defense industries, such as synthetic rubber and shipbuilding. After the war, the industry studies program resumed on a regular basis, and was supplemented by a number of industry studies based on the direct collection of data from employers. Budget restrictions after 1952 prevented the continuation of direct collection of data. Consequently, the preparation of industry measures is largely limited to those industries where readily available data can be used to construct measures.

In recent years, public interest in productivity has grown, and increases in output per employee hour have been recognized as important indicators of economic progress and a means to higher income levels, rather than merely a threat to job opportunities.

The industry studies cover a variety of manufacturing and nonmanufacturing industries at the 2-, 3-, and 4-digit Standard Industrial Classification level. Measures for these industries are published on an annual basis and are provided for most years between 1947 or 1958 and the most recent year for which data are available.

Coverage has been expanded to include industries in trade and services, and with the increasing importance of the public sector, to various functional areas in the Federal Government. Productivity measurement in the Federal Government was initiated by a request from the Joint Economic Committee in the fall of 1970 to the General Accounting Office in conjunction with the Office of Management and Budget and the Civil Service Commission (now Office of Personnel Management). A joint Federal productivity measurement task force consisting of these agencies, with technical assistance and support from BLS, was established. This task force collected data and constructed indexes for fiscal years 1967-71. In July 1973, the Office of Management and Budget endorsed the continuation of the project to measure Federal productivity, and BLS assumed full responsibility for collecting input, output, and related information, in addition to the development of productivity measures.

Since July 1973, the Bureau has been expanding coverage to include organizational units not previously covered, improving the quality of some of the input and output data, and refining the methodological pro-

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cedures used to construct productivity indexes. The measurement program is part of a multifaceted effort sponsored by the Office of Personnel Management and includes analysis, enhancement, and diffusion of productivity improvement ideas.

The Bureau is also expanding its productivity measurement program by explicitly accounting for other inputs besides labor in the industry measures and developing a supplementary set of productivity measures. The new measures are referred to as multifactor productivity measures.

The industry multifactor series are designed to measure changes in productivity by relating changes in an industry's output not only to changes in labor input but also to changes in capital and intermediate purchases. In addition to providing indicators of productivity change useful for analysis in their own right, such measures also are helpful in analyzing the causes of change in output per employee hour or labor productivity.

Methods and Sources

Industries

Output per employee hour

BLS computes an index of output per employee hour by dividing an output index by an index of aggregate employee hours. For most industries, measures are prepared separately relating output to (a) all employee hours, (b) production worker hours, and (c) nonproduction worker hours. (The standard definitions of production workers and nonproduction workers are used.) Three corresponding measures also are computed relating output to the number of employees. For industries in trade and services, measures are prepared relating output to the hours of all persons involved in producing that output, including self-employed and unpaid family workers.

Output

BLS industry output indexes are based on quantifiable units of products or services of the industry combined with fixed period weights. Whenever possible, physical quantities are used as the unit of measurement. For those industries lacking quantity data, constant-dollar value of shipments, sales, or revenue data are used to develop the output series. This procedure is used almost exclusively for the nongoods-producing industries. For manufacturing and mining industries, quantity data on physical output are usually most comprehensive for years covered by a census. To make maximum use of the comprehensive census data, output indexes are derived from data for two consecutive censuses; these indexes are referred to as benchmark indexes. For intercensal years, annual indexes are based on either physical output data (generally in less detail than for census years) or, if such data are not available, value of output adjusted for price change (the value of output in constant dollars). The annual series subsequently are adjusted to the benchmark levels for the census years.

Sources. Industry output indexes are prepared from basic data published by various public and private agencies, using the greatest level of detail available.

Data from the Bureau of the Census, U.S. Department of Commerce, are used extensively in developing output statistics for manufacturing, trade, and service industries. The Bureau of Mines, U.S. Department of the Interior, compiles most of the information for the mining and cement industries. Other important Government sources include the U.S. Department of Energy, the Department of Agriculture, the Fish and Wildlife Service, U.S. Department of the Interior, the Interstate Commerce Commission, the Internal Revenue Service, and the Civil Aeronautics Board. Important sources of trade association data include the Textile Economics Bureau, Inc., National Association of Hosiery Manufacturers, Inc., National Canners Association, Rubber Manufacturers Association, and the American Iron and Steel Institute.

For deflated value series, industry price indexes are derived from producer and consumer price indexes developed by the Bureau of Labor Statistics.

Employee hours

An index of employee hours is computed by dividing the aggregate employee hours for each year by the base-period aggregate. Employee hours are treated as homogeneous and additive with no distinction made between hours of different groups of employees. Data on changes in qualitative aspects of employee hours, such as skill, efficiency, health, experience, age, and sex of persons comprising the aggregate are not used and generally are not available. For mining and manufacturing industries, employee hour indexes are constructed for employees, production workers, and nonproduction workers. For service and trade industries, indexes are constructed for the hours of all persons, which includes paid employees, partners, proprietors, and unpaid family workers.

Sources. Industry employment and employee hour indexes are developed from basic data compiled by the Bureau of Labor Statistics or the Bureau of the Census. For trade and service industries, these data are supplemented with data from the Internal Revenue Service.

Federal Government

Indexes of output per employee year, output, and employee years for selected functional areas of Government activity[4] and for the more than 400 participating

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organizations are constructed in a manner similar to that described for industries. At the present time, these measures cover about 67 percent (1.9 million employee years) of the Federal civilian work force.

Ideally, a productivity index should relate final outputs to their associated direct and indirect input(s), and, in fact, the output data are final from the perspective of the funtional areas within which these data are classified. However, since the outputs of one organization may be consumed wholly or partially by another Federal organization in the production of its final outputs, all output indicators in the Federal sample may not be final from the perspective of a higher level organization; for example, the entire Federal Government. Therefore, the overall statistics do not represent "Federal productivity" but rather, the weighted average of the productivity changes of the measured Federal organizations included in the sample.

[4] The 28 functions are:
Audit of operations; Buildings and grounds; Communications; Education and training; Electric power production and distribution; Equipment maintenance; Finance and accounting; General support services; Information services; Legal and judicial activities; Library services; Loans and grants; Medical services; Military base services; Natural resources and environmental management; Personnel investigations; Personnel management; Postal services; Printing and duplication; Procurement; Records management; Regulation—compliance and enforcement; Regulation— rulemaking and licensing; Social services and benefits; Specialized manufacturing; Supply and inventory control; Traffic management; and Transpotation.

Presentation

BLS industry indexes are published annually in the bulletin, *Productivity Measures for Selected Industries.* A limited amount of the most current data is provided in an annual news release. As new industry indexes are developed, they are presented as articles in the *Monthly Labor Review.* The articles contain an analysis of productivity, output, and employment trends in the industry. Technical notes describing the methodology used to develop the indexes are available on request. Unpublished indexes for all 4-, 3-, and 2-digit SIC manufacturing industries are available for analytical purposes upon request. Federal Government indexes are published annually in the *Monthly Labor Review.*

Indexes of output per employee hour also are published in the *Statistical Abstract of the United States* and in the *Handbook of Labor Statistics.* Some indexes for earlier years are published in *Historical Statistics of the United States.*

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Highlights of Recent Trends in Output Per Employee Hour

Current developments

From 1980 to 1981, output per employee hour increased in nearly two-thirds of the industries for which data are presented in this report. In contrast, from 1979 to 1980, productivity fell in about two-thirds of the industries. The gains in industry productivity in 1981 were consistent with the performance of the nonfarm business sector as a whole, where productivity increased by 1.4 percent.

Among the large manufacturing industries, the steel industry recorded a gain of 9.0 percent in productivity after two consecutive years of productivity declines. Buoyed by strong sales to the oil and gas industry, steel output was up 9.8 percent in 1981, while hours grew by only 0.7 percent.

Another large manufacturing industry, motor vehicles, experienced a 4.7-percent growth in output per employee hour in 1981. This was in sharp contrast to the three previous years, in which productivity fell. Rebounding somewhat from a very poor year in 1980, output in the industry increased by 5.9 percent while employee hours grew by only 1.2 percent.

Among the other large manufacturing industries, the tire and inner tubes industry posted a gain in productivity of 13.3 percent. Output in this industry was up by 8.6 percent, sustained by demand from the replacement market, while hours continued to decline. Aside from demand strength, many old and inefficient tire plants were closed in 1980, which contributed to the sharp productivity gain 1981.

Other large manufacturing industries which recorded increases in productivity in 1981 included: Synthetic fibers (6.3 percent), bakery products (6.2 percent), gray iron foundries (5.9 percent), fluid milk (4.7 percent), fabricated structural metal (4.7 percent), corrugated and solid fiber boxes (2.7 percent), paper, paperboard, and pulp mills (2.0 percent), and electric motors and generators (1.3 percent).

However, three relatively large manufacturing industries posted productivity declines in 1981. In sawmills and planing mills, output per employee hour was down 2.6 percent, while the footwear industry recorded a falloff in productivity of 3.6 percent. The construction machinery and equipment industry also posted a drop in productivity—5.4 percent in 1981.

All the mining industries covered experienced productivity gains in 1981. Coal mining posted its second consecutive large productivity gain, rising 9.2 percent in 1981. Although coal output was down slightly (-1.3 percent) from the previous year, hours continued to decline sharply, resulting in the productivity gain. Productivity advances in the other mining industries were not as great as for coal. Iron mining (usable ore) rose 6.7 percent, copper mining (recoverable metal) increased 5.5 percent, and nonmetallic minerals gained 1.7 percent. Both copper and iron mining had large output increases in 1981, in contrast to sharp declines in 1980. The productivity gain in nonmetallic minerals, on the other hand, was based on a drop in output, due to poor demand from the construction industry, and an even larger decline in hours.

Productivity changes were mixed among transportation and utility industries. Productivity was up 5.4 percent in telephone communications as output grew 5.6 percent. In railroads, productivity rose 5.2 percent. Output in the railroad industry declined for the second straight year, dropping 0.7 percent, while hours continued to fall, declining 5.6 percent. After four consecutive years of declines, productivity in the trucking industry advanced 4.7 percent even though output dropped 4.9 percent; the number of employees was down by 9.2 percent. On the other hand, productivity registered a small decline of 0.3 percent in the air transportation industry. The general economic downturn and the air traffic controllers' strike contributed to the falloff in productivity. Productivity also fell in both gas (-3.8 percent) and electric utilities (-0.7 percent). Output was down in gas utilities as many consumers curtailed usage due to rising prices, while hours were up due to the growing number of customers. Output was up in electric utilities only 0.8 percent, well below the long-term rate of 6.6 percent, while hours grew 1.6 percent, resulting in the productivity falloff. Productivity dropped sharply (-8.3 percent) in petroleum pipelines as output fell for the second consecutive year due to declining demand for petroleum products, while hours increased.

In trade and services, productivity changes also were varied. Productivity grew 1.5 percent in retail food stores, as output was up 1.9 percent and hours grew 0.4 percent. New car dealer productivity was up 1.4 percent. Gasoline service station productivity rose 1.2 percent. Output was down 2.1 percent in this industry, as demand was off due to increased gasoline prices and

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more fuel efficient cars, while hours fell even more as marginal stations were closed and self-service stations became more prevalent. Productivity in both eating and drinking places and hotels and motels declined 1.9 percent as small gains in output were more than compensated for by larger gains in hours. Productivity in drug stores fell 2.7 percent as output declined 1.9 percent and hours were up slightly. In the laundry and cleaning industry, productivity fell 3.2 percent due to a continued decline in demand for the industry's services resulting in an output drop of 7.2 percent, while hours fell 4.2 percent.

Long-term trends

With one exception, all of the industries in this report recorded average annual increases in productivity over the long term (1947-81 for many of these industries). The metal forming machine tools industry recorded an average annual change in productivity of -0.1 percent over the 1958-81 period. A combination of factors worked against a productivity increase in the machine tools industry, including the tendency of machine tool firms to keep highly skilled workers on the payroll even when output falls during cyclical slowdowns. Additionally, machine tools are not mass produced although they may make mass production processes possible in user industries. The parts and components of a finished machine tool are usually made in relatively small batches and require comparatively large amounts of labor.

On the other hand, the wet corn milling industry posted the highest long-term rate of growth in productivity (7.1 percent per year). Growth in this industry's output and productivity was modest until 1972 when an explosion in output resulted from the rapid market penetration of high fructose and glucose corn syrups. The industry, previously highly capital intensive, became even more so with large infusions of capital.

Although the rates of productivity change varied widely among the industries during the 1976-81 period (see chart 1), three-fourths of the industries recorded lower average annual gains in this more recent period than during the 1947-76 period. This experience matches the productivity record of the nonfarm business economy as a whole. From 1947 to 1976, productivity in this sector grew 2.3 percent per year while from 1976 to 1981 the annual growth rate was only 0.1 percent. The slower growth in productivity among the industries included in this report was associated with less rapid output growth in the later period.

However, there were a few notable exceptions to the falloff in productivity growth during the 1976-81 period. In addition to wet corn milling, the ceramic wall and floor tile industry recorded a substantial improvement in the rate of productivity growth in the last few years—7.4 percent a year. Coupled with changes in material handling procedures, a new technique for firing tile became widespread. These changes resulted in significant labor savings for the industry. The wood office furniture industry posted a 7.0-percent annual growth in productivity, far outstripping its rate of 1.1 percent in the previous period. Productivity was enhanced by substantial output growth in the late seventies as wood furniture captured a large share of the market from metal office furniture.

Among the industries that experienced productivity declines during the 1976-81 period, the brick and structural clay tile industry dropped the most (-5.7 percent per year). Other industries in which productivity declined substantially (more than 2 percent per year) during the period were: Cosmetics and other toiletries (-3.4 percent), laundry and cleaning services (-3.2 percent), hydraulic cement (-2.5 percent), petroleum pipelines (-2.2 percent), and blended and prepared flour (-2.1 percent). (See table 1.)

New measures

Millwork SIC 2431. Labor productivity in the millwork industry rose at an average annual rate of 1.4 percent from 1958 to 1980, a modest advance when compared with total manufacturing. Over this period, output in millwork increased at a rate of 2.7 percent annually and employee hours at 1.3 percent. The productivity rise partly reflected low growth in capital investment, particularly over the past decade, and, evidently, slow diffusion of modernized production technologies. These factors, combined with instability in demand for the industry's products, retarded productivity growth.

Approximately three-fourths of the industry's output is used in residential housing, including additions and alterations; small amounts of output are used in commercial and educational buildings, prefabricated wooden buildings, and in trailers and other transportation equipment. Millwork output is thus linked mainly to residential construction where fluctuations have been frequent and substantial.

The basic technology used in millwork plants dates from the 1930's and 1940's; however, advances in production techniques have been numerous. For example, the versatility of machines fabricating moldings has been greatly extended so that a large variety of complex molding profiles can be cut and grooved at great speeds without loss of precision and insignificnt loss in setup time. Significant advances have also been made in adhesive applications. High-speed production requires rapid curing, and the gluing process is therefore usually an integral part of the production process. Certain radio-frequency gluing devices have reduced curing time from 20 to 2 minutes. A modest trend toward automated systems in the industry is underway, furthered

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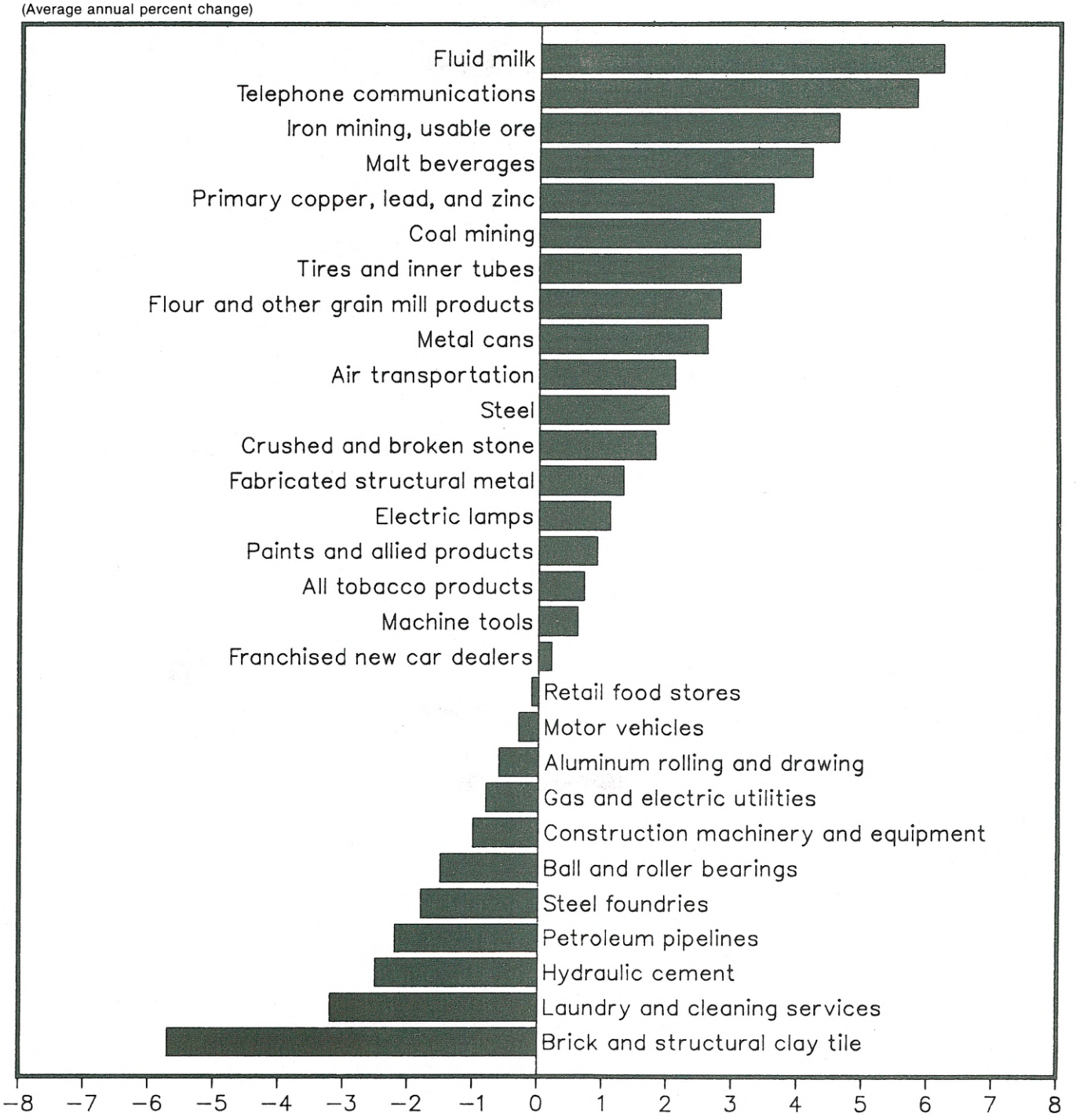
Chart 1. Growth in output per employee hour in selected industries, 1976-81
(Average annual percent change)



by the declining costs of numerical conrols, which more and more entail one-station systems featuring microcomputers. This trend also involves computer-controlled materials handling systems, robotized transfer and palletizing, and carousels interfacing with conveyors, robots, and other material handling devices.

Office furniture (SIC 252). Between 1958 and 1980, output per employee hour in the office furniture industry advanced at an annual rate of 1.8 percent, substantially below the 2.8-percent rate for all manufacturing. The productivity gain in the office furniture industry resulted from growth in output averaging 5.5 percent annually and employee hours averaging 3.6 percent. The growth in productivity in the industry has been comparatively low, in large part because of relatively short production runs engendered by product proliferation.

A number of factors have shaped the demand for office furniture and the industry's output growth. Some

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of these factors are the growth of the white-collar work force, the amount of available office space, replacement demand, and the introduction of new products. Undoubtedly, the most important factor influencing the long-term output growth has been the increase of the white-collar work force. During the period under study (1958-80), white-collar employment increased from about 27 million to nearly 53 million and currently accounts for slightly more than one-half of the total employed work force.

Productivity growth in the industry has been enhanced by the increased use of more automatic machinery; new materials such as particleboard, quick-setting glues, and improved finishes; better workflow layout; and computerized recordkeeping.

Cosmetics and other toiletries (SIC 2844). Productivity increased at an average annual rate of 4.0 percent from 1958 to 1980—substantially above the 2.8-percent rate for the manufacturing sector. This growth was associated with average annual increases of 7.3 percent in output and 3.1 percent in employee hours. Productivity gains have resulted primarily from a trend toward fewer and larger plants producing a greater level of output, and continued improvements in production and packaging operations.

The changes in output per employee hour have not been steady. Since 1958, annual increases in productivity have ranged from a high of 14.9 percent to a low of 0.4 percent. Declines in productivity occurred in 6 years, the most recent in 1980 when a drop of 11.4 percent was recorded. The decline in 1980 was the largest single-year decline noted.

Productivity should benefit from continued improvements in the production process and in the equipment used. Increased utilization of computer technology may also contribute to productivity gains. Substantial demand for the industry's products is expected to continue.

Hand and edge tools (SIC 3423). As measured by output per employee hour, productivity in the hand and edge tool industry grew at an average annual rate of only 1.3 percent during 1958-80, compared with 2.8 percent for all manufacturing. Output increased at a rate of 3.3 percent and employee hours at a 2.0 percent rate.

Productivity gains have been linked to the continuing mechanization of the production process. The use of robots in material handling operations has been a factor in this regard. Improvements in the ovens used to heat the metal for the forging operation have contributed to faster production rates. The adoption of horizontal impact forging equipment by some plants has resulted in improved production efficiencies. The adoption of cold forming techniques is also aiding productivity. In the cold forming process, dies are still used to give the workpieces their final shape. However, advances in the feeding mechanisms permit preforming of the pieces to such an extent that they can enter the dies without the usual need for heating.

Farm and garden machinery (SIC 352). Productivity in farm and garden machinery manufacturing grew at a rate of 2.6 percent from 1958 to 1980, with output increasing at 4.2 percent per year and hours growing 1.5 percent per year. The rate of productivity gain was about the same as the average for all manufacturing industries over the period measured.

Productivity growth in the farm machinery industry can be divided into three distinct periods. During 1958-65, productivity grew at a rate of 1.7 percent; in 1965-74, it accelerated to a rate of 3.3 percent per year; and in 1974-80, it slowed to 0.2 percent. The higher rate of gain during the 1965-74 period can be associated with a number of years of very high output and productivity growth, fueled by dramatic increases in farm income.

The introduction of new technology including numerical control of machine tools, computer-controlled warehousing facilities, and industrial robots, which have been adopted mainly by the larger firms in the industry, has aided productivity growth. On the other hand, productivity growth has been moderated by the variable nature of demand, which is affected by cyclical changes and changes in farm income. For example, almost every decline in productivity can be associated with a drop in output. In turn, industry output declines tend to be roughly coincident with downturns in the economy.

Pumps and compressors (SIC 3561,3563). Output per employee hour in pump and compressor manufacturing rose at an average annual rate of 2.1 percent between 1958 and 1980—compared with a rate of 2.8 percent for manufacturing as a whole. Output increased 4.7 percent a year, employee hours 2.6 percent.

Pumps and compressors are used throughout manufacturing and in many nonmanufacturing industries, as well as agriculture. Pumps are the second most common machine in use after the electric motor. Compressors generate compressed air, which may be regarded as a form of energy ranking in breadth of use only below electricity, gas, and water. Growth in the output of pumps and compressors was, in general, related to expansion in industrial and public utility demand, gains in residential and associated public works construction, and intensified needs of energy-related extractive and pipeline industries. Foreign trade, too, played an important role in sustaining output: About one fifth of pump and compressor production was exported between 1972 and 1978.

Small lot production is the rule in pump and compressor establishments. Pumps and compressors are

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often large machines, manufactured to customer specifications. While many of these machines are composed of standard parts, the economies associated with mass production are generally not available. The production process must constantly be adapted so as to cope with the many design, casting, and machining requirements that arise. Such adaptation was facilitated by the advent of numerically controlled machine tools in the sixties, and the introduction of computer-aided design (CAD) into engineering practice. Numerical controls (NC) and CAD have been important sources of productivity advances in the industry.

Commercial banking (SIC 602). Output per employee hour in commercial banking rose at an average annual rate of 1.3 percent between 1967 and 1980—nearly the same as for the nonfarm business sector as a whole (1.4 percent). Output over the period examined rose at a rate of 6.0 percent per year, while employee hours grew 4.6 percent. The rise in banking productivity was associated with strongly expanding customer services and with advances in computer technology and their rapid diffusion throughout the industry. However, the spread of branch banking, while enhancing the convenience of access to banking services, somewhat retarded productivity improvement, partly because scale economies became less favorable.

The sources of the industry's strong output growth were the boom conditions of the early seventies and the financial needs they generated; rapid increases in check transactions; relatively greater reliance by business on external funds; and continuously heavy demand for consumer and real estate credit. Also, commercial banks expanded their share of major types of such credit, as well as of time deposits. Moreover, they emphasized the retailing aspects of their services and consequently accelerated branching. Trust department functions also grew apace as pension and welfare funds proliferated.

The banking industry has been radically transformed by electronic data processing. Although computer developments during the fifties embodied the principle of machine readability, it was the introduction of magnetic ink character recognition (MICR) in 1958 that made the breakthrough of electronic data processing in banking possible. The computer became an indispensable and major factor in improving banking productivity, and the technology has rapidly permeated the industry.

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Table 1. Selected industries: Employment, 1981, and average annual rates of change in output per employee hour, 1976–81

SIC code	Industry	Employment, 1981 (thousands)			Output per employee hour: Average annual rate of change, 1976–81 (percent)[1]		
		All employees	Production workers	Non-production workers	All employees	Production workers	Non-production workers[2]
	Mining						
1011	Iron mining, crude ore	21	17	4	5.3	5.5	4.5
1011	Iron mining, usable ore	21	17	4	4.6	4.8	3.8
1021	Copper mining, crude ore	36	28	8	0.1	0.1	0.1
1021	Copper mining, recoverable metal	36	28	8	−0.8	−0.8	−0.8
111, 121	Coal mining	222	184	38	3.4	4.0	0.1
121	Bituminous coal and lignite mining	219	181	38	3.4	4.1	0.1
14	Nonmetallic minerals, except fuels	119	91	28	−0.1	0.5	−2.4
142	Crushed and broken stone	37	30	7	1.8	2.0	0.9
	Manufacturing						
2026	Fluid milk	96	[3]	[3]	6.2	[3]	[3]
203	Preserved fruits and vegetables	240	197	43	[4]0.1	[4]0.6	[4]−2.2
2033	Canned fruits and vegetables	91	75	16	[4]−0.2	[4]0.6	[4]−5.5
204	Grain mill products	140	97	43	[4]3.6	[4]3.5	[4]3.8
2041	Flour and other grain mill products	26	16	10	2.8	1.9	5.8
2043	Cereal breakfast foods	17	13	4	[4]2.0	[4]1.2	[4]6.7
2044	Rice milling	5	4	1	[4]4.3	[4]6.5	[4]−4.1
2045	Blended and prepared flour	8	8	2	[4]−2.1	[4]−3.2	[4]1.1
2046	Wet corn milling	13	10	3	[4]10.3	[4]11.4	[4]7.5
2047, 48	Prepared feeds for animals and fowls	71	48	23	[4]3.5	[4]4.0	[4]2.8
205	Bakery products	219	127	92	−0.2	−0.5	0.4
2061, 62, 63	Sugar	32	23	9	2.1	1.5	5.0
2061, 62	Raw and refined cane sugar	20	14	6	[4]3.8	[4]2.9	[4]7.1
2063	Beet sugar	12	9	3	[4]3.0	[4]4.0	[4]−3.9
2065	Candy and confectionery products	56	45	11	[3]	[3]	[3]
2082	Malt beverages	50	32	18	4.2	4.2	4.1
2086	Bottled and canned soft drinks	137	45	92	3.5	5.5	2.4
2111, 21, 31	All tobacco products	58	45	13	0.7	1.5	−3.6
2111, 31	Cigarettes, chewing and smoking tobacco	51	39	12	0.5	1.3	−3.8
2121	Cigars	7	6	1	3.0	2.8	5.5
2251, 52	Hosiery	65	58	7	1.5	2.0	−2.3
2281	Nonwool yarn mills	82	75	7	1.0	1.3	−3.1
2421	Sawmills and planing mills, general	172	152	20	−0.3	0.5	−5.6
2431	Millwork	67	54	13	[4]−1.7	[4]−1.0	[4]−5.0
2435, 36	Veneer and plywood	64	57	7	[4]−0.3	[4]0.4	[4]−5.6
2435	Hardwood veneer and plywood	25	22	3	[4]2.6	[4]2.8	[4]0.5
2436	Softwood veneer and plywood	39	35	4	[4]−1.5	[4]−0.5	[4]−8.4
251	Household furniture	299	250	49	[4]0.1	[4]0.5	[4]−1.9
2511, 17	Wood household furniture	140	122	18	[4]−0.7	[4]−0.2	[4]−4.1
2512	Upholstered household furniture	89	73	16	[4]1.2	[4]1.3	[4]0.8
2514	Metal household furniture	31	25	6	[4]−1.7	[4]−2.0	[4]−0.8
2515	Mattresses and bedsprings	31	24	7	[4]2.7	[4]3.5	[4]0.3
252	Office furniture	54	42	12	[4]4.7	[4]5.3	[4]2.7
2521	Wood office furniture	22	19	3	[4]7.0	[4]9.6	[4]−2.8
2522	Metal office furniture	32	24	8	[4]3.2	[4]2.9	[4]4.3
2611, 21, 31, 61	Paper, paperboard, and pulp mills	267	202	65	2.3	2.5	1.4
2643	Paper and plastic bags	50	39	11	[4]−1.6	[4]−1.4	[4]−2.2
2651	Folding paperboard boxes	43	34	9	−1.6	−1.5	−2.2
2653	Corrugated and solid fiber boxes	103	76	27	2.7	3.1	1.6
2823, 24	Synthetic fibers	102	74	28	6.2	6.1	6.6
2834	Pharmaceutical preparations	158	77	81	[4]2.6	[4]2.1	[3]
2841	Soaps and detergents	44	29	15	[4]2.0	[4]1.6	[4]2.8
2844	Cosmetics and other toiletries	62	41	21	[4]−3.4	[4]−3.8	[4]−2.6
2851	Paints and allied products	63	31	32	0.9	1.8	[5]
2911	Petroleum refining	174	105	69	[4]−0.3	[4]1.3	[4]−3.8
3011	Tires and inner tubes	107	75	32	3.1	3.2	2.7
314	Footwear	143	123	20	−0.6	−0.4	−2.1
3221	Glass containers	68	59	9	3.3	3.5	1.7
3241	Hydraulic cement	30	24	6	−2.5	−2.4	−3.2
325	Structural clay products	41	31	10	−0.6	[5]	−3.2
3251, 53, 59	Clay construction products	30	23	7	−2.2	−1.4	−5.6
3251	Brick and structural clay tile	17	13	4	−5.7	−4.0	−12.4
3253	Ceramic wall and floor tile	9	7	2	[4]7.4	[4]6.6	[4]11.4

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Table 1. Selected industries: Employment, 1981, and average annual rates of change in output per employee hour, 1976–81—Continued

SIC code	Industry	Employment, 1981 (thousands)			Output per employee hour: Average annual rate of change, 1976-81 (percent)[1]		
		All employees	Production workers	Non-production workers	All employees	Production workers	Non-production workers[2]
	Manufacturing—Continued						
3255	Clay refractories	11	8	3	4.3	4.6	3.4
3271, 72	Concrete products	85	62	23	[4]–0.9	[4]–0.1	[4]–3.2
3273	Ready-mixed concrete	88	[3]	[3]	[4]–1.2	[3]	[3]
331	Steel	505	391	114	2.0	2.3	1.1
3321	Gray iron foundries	121	98	23	–1.0	[5]	–5.8
3324, 25	Steel foundries	64	49	15	–1.8	–1.6	–2.3
3331, 32, 33	Primary copper, lead, and zinc	22	17	5	3.6	3.9	2.4
3331	Primary copper	14	11	3	5.1	5.4	4.2
3334	Primary aluminum	37	28	9	–0.1	0.6	–2.6
3351	Copper rolling and drawing	29	22	7	1.8	2.3	[5]
3353, 54, 55	Aluminum rolling and drawing	72	52	20	–0.6	–0.1	–2.5
3411	Metal cans	58	50	8	2.6	2.8	1.7
3423	Hand and edge tools	46	35	11	[4]0.7	[4]1.4	[4]–1.8
3441	Fabricated structural metal	101	72	29	1.3	0.9	2.5
352	Farm and garden machinery	156	105	51	[4]–0.7	([4] [5])	[4]–2.3
3523	Farm machinery	135	90	45	[4]–1.6	[4]–1.1	[4]–3.1
3524	Lawn and garden equipment	21	15	6	[4]4.0	[4]5.1	[4]1.2
3531	Construction machinery and equipment	143	95	48	–1.0	–0.1	–3.1
3541, 42	Machine tools	104	67	37	0.6	0.7	0.3
3541	Metal cutting machine tools	80	52	28	1.4	1.1	2.0
3542	Metal forming machine tools	24	15	9	–2.0	–0.7	–4.7
3561, 63	Pumps and compressors	94	56	38	[4]0.9	[4]0.9	[4]0.9
3561	Pumps and pumping equipment	62	37	25	[4]1.0	[4]1.0	[4]1.0
3563	Air and gas compressors	32	19	13	[4]0.5	[4]0.5	[4]0.4
3562	Ball and roller bearings	57	44	13	–1.5	–1.8	–0.3
3612	Transformers	54	38	16	[4]5.1	[4]4.5	[4]6.4
3621	Motors and generators	125	96	29	–0.4	0.3	–2.8
3631, 32, 33, 39	Major household appliances	93	74	19	2.4	2.1	3.5
3631	Household cooking equipment	23	18	5	2.6	1.9	5.3
3632	Household refrigerators and freezers	34	27	7	4.3	3.5	8.0
3633	Household laundry equipment	21	17	4	0.2	0.1	0.6
3639	Household appliances, n.e.c.	15	12	3	1.3	1.7	–0.4
3641	Electric lamps	33	29	4	1.1	1.1	1.1
3645, 46, 47, 48	Lighting fixtures	65	49	16	[4]–0.7	([4] [5])	[4]–2.9
3651	Radio and television receiving sets	82	57	25	[4]4.4	[4]5.1	[4]2.2
371	Motor vehicles and equipment	784	583	201	–0.3	1.1	–4.4
	Other						
401 class I	Railroad transportation, revenue traffic	457	395	62	3.1	3.4	1.4
401 class I	Railroad transportation, car miles	457	395	62	[4]1.5	[4]1.7	[4]0.6
4111, 413, 414 pts	Bus carriers, class I	36	[3]	[3]	[4 6]2.4	[3]	[3]
4213 part	Intercity trucking	670	[3]	[3]	–0.8	[3]	[3]
4213 part	Intercity trucking (general freight)	413	[3]	[3]	–1.7	[3]	[3]
4511, 4521 part	Air transportation	358	[3]	[3]	[6]2.1	[3]	[3]
4612, 13	Petroleum pipelines	22	15	7	–2.2	–1.0	[3]
4811	Telephone communications	1,076	[7]782	[8]294	5.8	[3]	[3]
491, 92, 93	Gas and electric utilities	777	[7]632	[8]145	–0.8	[7]–0.5	[3]
491, 493 part	Electric utilities	561	[3]	[3]	–0.9	[3]	[3]
492, 493 part	Gas utilities	216	[3]	[3]	–0.5	[3]	[3]
54	Retail food stores[9]	2,429	[3]	[3]	–0.1	[3]	[3]
5511	Franchised new car dealers	706	[3]	[3]	0.2	[3]	[3]
5541	Gasoline service stations[9]	691	[3]	[3]	2.1	[3]	[3]
58	Eating and drinking places[9]	5,097	[3]	[3]	–1.8	[3]	[3]
5912	Drug and proprietary stores[9]	528	[3]	[3]	1.2	[3]	[3]
602	Commercial banking	1,482	[3]	[3]	[4]–0.6	[3]	[3]
7011	Hotels, motels, and tourist courts[9]	1,179	[3]	[3]	–0.6	[3]	[3]
721	Laundry and cleaning services[9]	419	[3]	[3]	–3.2	[3]	[3]

[1] Based on the linear least squares trends of the logarithms of the index numbers.
[2] Rates of change for nonproduction worker hours are subject to a wider margin of error than other rates shown.
[3] Not available.
[4] 1976–80.
[5] Less than 0.05 percent.
[6] Output per employee.
[7] Nonsupervisory personnel.
[8] Supervisory personnel and force account construction workers.
[9] Data relate to all persons, including proprietors, partners, and unpaid family workers.

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Measuring productivity in service industries

The growth of the service economy presents special challenges for productivity analysts; output is often difficult to quantify, and measurement of labor input requires great care

JEROME A. MARK

The increased importance of service industries over the last two decades and current concern over productivity growth have stimulated interest in productivity measures for this expanding sector of the economy.

The service sector, as defined here, encompasses the major industry groupings of trade, finance, insurance, communications, public utilities, transportation, and government, as well as business and personal services. It accounts for almost three-fourths of the Nation's employment and provides the greatest potential, as well as some of the greatest difficulties, for developing productivity measures.

Over the last decade, the Bureau of Labor Statistics has been expanding the number of service industries for which it publishes productivity measures, and at present provides measures for 16 industries, representing almost a third of the employment in the sector. The Bureau is continuing to develop additional measures, and hopes eventually to extend coverage to most of the service sector.

This article describes that effort, discusses some of the problems of measuring productivity, particularly labor productivity in service industries, and explains how the Bureau is working to resolve some of the problems.

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Linking output to input

Productivity measures relate real physical output to real input. They range from single factor measures, such as output per unit of labor input or output per unit of capital input, to measures of output per unit of multifactor input. Such measures also reflect changes in technology, scale of production, educational levels of workers, managerial techniques, and many other factors in addition to the contributions of the particular inputs.

Although BLS is currently developing multifactor productivity measures, at present, the published productivity measures relate output to labor input. This is the most extensively developed and widely used productivity measure because of its relevence to economic analyses and because, as a practical matter, labor is the most easily measured input.

Problems of measuring output

In many ways, the problems of measuring output in the service industries are similar to those of measuring output in the goods-producing industries. That is, the output indicator must be quantifiable and independent of the input measures. If an output measure for an activity is based on an input measure, as is the case in some instances in the national accounts, obviously no change in productivity can be ascertained. In the case of general government, for example, output in the national

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income and product accounts is measured in terms of compensation of government employees. The deflated or constant-dollar measure is derived from changes in employment. Hence, changes in the output measure are closely related to changes in the input measure.

It is also important to distinguish between intermediate and final services. In productivity measurement, we attempt to ensure that the indicators represent output flowing from the industry being measured rather than intermediate steps in the service flow. In this sense, productivity measurement differs from work measurement, which generally refers to the analysis of the operation of an activity and the labor requirements at each intermediate stage. Productivity measurement refers only to the final service and its relationship to input.

For example, in the trucking industry, a count of the ton-miles of freight moved would be the appropriate indicator of the final output—that is, the result of all the activities of the industry. The intermediate steps, such as pickup and delivery, platform work, billing, and collecting, are considered to be subsumed in the final output.

In the case of an organization or an industry providing one type of service, output is merely a count of the units of this service, however defined. In the more usual case of an industry producing a number of heterogeneous services, the various units must be expressed in some common basis for aggregation. For example, the output of franchised new-car dealerships should be a combination of the number of cars sold and the repair activities of the dealers, with appropriate weighting.

To obtain a productivity measure that is an average of the changes of individual components, the appropriate weights for combining the various elements in the output measure are in terms of their factor input requirements. In a labor productivity measure, the weights are unit labor requirements.

Homogeneity among services, after considerations of quality and specifications, is indicated by similarity in unit labor requirements. In this way, the output measure for the development of labor productivity statistics differs from more traditional production measures based on total price or value-added price weighting.

When there are quality changes within the service, adjustments must be made in the output measure to account for the fact that the output is no longer the same homogeneous unit. However, the indicator of quality change for labor productivity measurement differs from the usual concept of quality change associated with consumer price measurements in that it reflects differences in producers' labor requirements or labor costs rather than consumer utility differences.

Ideally, then, the output measure should incorporate data on the number of services provided, differentiated by unit labor requirements, and in sufficient detail to adjust for quality changes. In practice, however, such data are not generally available for service industries (and, in many cases, for goods-producing industries as well). As a result, approximations based on alternative approaches must be used.

The principal alternative is to remove the change in price from the change in total value of the volume of services. This approach is tantamount to price weighting quantities of services provided. Insofar as price relationships among the various component services of a service industry are similar to the unit labor requirements or unit labor costs, this is a close approximation of the desired measure. And because it is easier to measure price change for a specified group of services than it is to measure the number of services provided directly, this is the approach most generally followed.

However, the adjustment requires data in sufficient detail to adequately represent the price trends of the components included in the price change. Otherwise, price movements of the covered areas will be implicitly imputed to the uncovered areas. But because the relationship among the price movements of similar services is much stronger than the relationship among quantity changes, this alternative still has greater viability than imputing quantity changes for uncovered services.

In practice, BLS uses the two approaches to develop output measures for service industries. In some instances, quantity data are available, particularly for utilities and transportation industries. In others, price deflation is employed, and for some, deflation at lower levels of aggregation is combined with labor input weighting at higher levels. For example, in developing the measure for gasoline service stations, gasoline sales, repair, and other services are deflated separately and summed, but in the case of retail food stores, sales by major department are deflated and combined with employee labor cost weights.

Measuring labor input

With regard to labor input measures, the principal problems are data gaps. Information is needed on hours worked by all persons—nonsupervisory workers, supervisory workers, and self-employed and unpaid family workers—in an individual industry. But although data on hours worked are collected by various government agencies as part of such ongoing programs as the Bureau's occupational safety and health surveys, they tend to be limited in scope, or otherwise inconsistent with the output data developed.

The principal source of data on employment and hours is the BLS Current Employment Survey of establishments. This payroll series provides good measures of the employment and hours of nonsupervisory workers. However, it is collected on an hours paid basis, rather

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than on an hours worked basis. To the extent that hours paid for but not worked are changing, this measure has limitations. To overcome this problem, the Bureau is measuring hours at work as a proportion of hours paid for a sample of establishments in the survey and will use these data to adjust the industry hours paid series.

In general, data on the hours of supervisory workers are poor. Although employment data on supervisory workers are available from the payroll survey, hours data are not. Other sources, such as the censuses of population, are used to estimate this component of the labor input measure.

Data on the number of self-employed, an important component of the input series measure for retail industries, come from the Internal Revenue Service (IRS). The IRS data lag current estimates by 3 years, but may be projected forward with special tabulations from the Current Population Survey (CPS).

These CPS tabulations break out the numbers and hours of self-employed and unpaid family workers at the 3-digit Standard Industrial Classification level. Although the sample size at this level is small and the statistical error is high, the data are the only continuous series of the number and hours for unpaid family workers and for the hours of the self-employed.

The measures derived from these data are unweighted hours; that is, the hours of various types of employees are treated as being equally productive. This would not be a problem if the proportions of workers at different levels of productivity were constant over time. However, to the extent that there are changes in the composition of the work force, such as age, sex, and occupational mix, it may be desirable to adjust the labor input measure for these changes which otherwise would be reflected in the productivity measure.

Data gaps hamper the making of these adjustments. Industry data on employment and hours by age and occupation are limited, although various sources, such as the CPS and BLS occupational employment surveys, provide some pieces. And while worker groups may be differentiated into productivity levels according to their wages or compensation, pay is a factor which may reflect other than productivity differences.[1]

Measures for service industries

At present, BLS publishes indexes of output per unit of labor input for industries in each major service activity—trade, communications, transportation, utilities, and business and personal services, a total of 16 separate measures. Data for these industries, presented in table 1, indicate a wide range of productivity growth since 1973, the year in which a productivity slowdown for the general business economy appeared to begin. In many cases, the growth rates exceeded those for industries in the goods-producing sector.

Table 1. Average annual rates of change in output per hour of all employees in selected service industries, 1965–73 and 1973–80

[In percent]

SIC Code	Industry	1965–73	1973–80
	Transportation:		
401	Railroad transportation, revenue traffic	4.2	2.2
4111;4131;414 (parts)	Bus carriers	−1.5	−0.4
4213 (parts)	Intercity trucking[1]	2.7	0.5
4511	Air transportation[1]	5.3	4.3
4612,13	Petroleum pipelines	7.9	0.0
	Communications:		
4811	Telephone communications	4.7	7.0
	Public utilities:		
491;492;493	Gas and electric utilities	4.9	0.7
491;493 (part)	Electric utilities	5.4	1.3
492;493 (part)	Gas utilities	3.9	−0.4
	Trade:		
54	Retail food stores	2.2	−1.2
5511	Franchised new car dealers	2.6	0.5
5541	Gasoline service stations	4.9	3.1
58	Eating and drinking places	1.1	−1.0
5912	Drug and proprietary stores	6.2	1.9
	Services:		
7011	Hotels, motels, and tourist courts	1.8	1.3
721	Laundry and cleaning services	1.7	−1.1

[1] Output per employee.

In addition, a measure for commercial banking is being developed, and work has begun on measures for the insurance and hospital industries. In a related area, productivity measures for Federal agencies which provide functions such as recordkeeping, insurance, libraries, building and grounds maintenance, and medical services have been published.

It is not possible within the confines of this article to discuss all of the productivity measures prepared by the Bureau, but reference to some of the more important and interesting ones in each of the major areas can illustrate the difficulties encountered in constructing such statistics.

Trade. The Bureau has published measures for retail trade industries since 1975 (with the data beginning in 1958). At present, statistics are published for five important industries—retail food stores, new car dealerships, gasoline service stations, eating and drinking places, and drugstores. Work is underway on a measure for apparel stores, including shoe stores, to be published separately. The effort to develop productivity measures in the wholesale area has not yet succeeded.

For most retail trade industries, data on gross sales in current dollars, deflated by the appropriate price indexes, are used to estimate real output. This method, as mentioned earlier, can yield good estimates of real output. However, such measures can reflect shifts among services with different values, but having the same labor requirements. Therefore, the overall industry productivi-

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ty index can show movements without any change in component elements.

In retail industries, a large portion of the value of sales has been provided by the manufacturer and the wholesaler of the product sold. A net output measure would be desirable, because it would most closely correspond to the value added by the retailer. However, a gross or total sales measure will yield the same results as a net or value-added measure if the value added as a percent of sales (gross margin) does not change over time. Available data indicate that, among retail industries for which productivity data are published, gross margins have not changed significantly over time.

To incorporate labor input weights, the indexes for most of the retail trade industries are developed in two stages. First, deflated output measures based on sales volume are developed for detailed merchandise lines. These are aggregated to higher levels and then combined with labor costs weights. For example, in retail food stores, sales for 13 key merchandise lines are deflated using specially prepared price indexes based on CPI components. The merchandise lines are aggregated to five department lines—meat, produce, frozen food, dry groceries, and dairy and all others. These are then aggregated with labor cost weights from Department of Agriculture data to develop the overall output measure for groceries. The labor input data for retail trade productivity statistics are generally derived from the Bureau's establishment survey, supplemented by IRS and CPS data.

Transportation. BLS publishes productivity measures for five transportation industries—railroads, intercity trucking, intercity buses, air transportation, and petroleum pipelines. These measures cover 57 percent of transportation employment.

Conceptually, productivity measures for the transportation industries are easier to develop than those for other non-goods producing industries. This is because transportation industry output—the movement of goods or passengers or both from one point to another—is more easily quantified. Output units in transportation have two dimensions, amount and distance; they reflect not only how much has been transported, but also how far. As such, ton-miles, passenger-miles, barrel-miles, and so forth are the primary output indicators for these industries.

Although the basic information for developing good transportation productivity measures is available and is, of course, being used, there are some data gaps that place certain limitations on the BLS measures. For example, it is sometimes impossible to adjust the productivity measures adequately for changes in the average length of haul. The unit labor requirements associated with the movement of goods and passengers are usually greater for short hauls than for long hauls. Therefore, a shift from a long haul to a short haul trip or vice versa could be reflected as a change in productivity although only the mix of trips had changed.

For the two major freight-carrying industries, railroads and trucking, undifferentiated ton-mile information is reported for total freight operations. In trucking, the ton-mile data are also reported separately for three types of carriers—general, contract, and others. But output measures should reflect the *kinds* of commodities handled and the average distance they are moved. The preferred way to develop these measures would be to combine the tonnage and the average haul of each commodity by its respective labor requirements and aggregate the results for all commodities transported. Unfortunately, this cannot be done with available data.

However, supplementary information on tonnage for railroads is available from the ICC for about 200 commodity lines, ranging from agricultural and mining products to motor vehicles and scientific instruments. Until recently, similar information was also available for the trucking industry. BLS uses these data to adjust the overall measure of freight ton-miles for changes in the composition of goods carried.

Although this commodity adjustment is a significant improvement, refinements to the undifferentiated ton-miles cannot be developed to the extent desired. For example, separate labor requirements data are not available for weighting the individual commodity groups. The commodity index adjustments are therefore made in terms of unit revenue weights, the underlying assumption being that differences between labor requirements among commodities are similar to differences in terms of unit revenues. This does not seem unreasonable because labor costs constitute more than half of each industry's total operating costs, although the proportion could conceivably differ by commodity. For railroads, the adjusted freight ton-mile measure is combined with a measure of revenue passenger-miles to obtain the total industry output index.

For air transportation and trucking, employment is the only available measure of labor input. Thus, the productivity measures for these two industries should be interpreted with caution, for if changes occur in the average workweek, the trends in productivity would not show the true relationship between output and labor time expended on the output.

The transportation industries for which BLS publishes productivity measures all are regulated to some degree by the Federal Government. Recent efforts to reduce the paperwork burden, coupled with the effects of deregulation, have acted to eliminate some of the operating statistics previously published. As a result, some

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productivity measures have had to be extended on the basis of more limited information. The outlook for expanding the data base, at least in the near future, is not favorable. However, BLS is cooperating with other government agencies to ensure that adequate statistics for transportation industries remain available.

Communications. The BLS productivity measure for telephone communications covers about four-fifths of the employment in the communications sector. The output index is derived from revenues of all telephone companies reporting to the Federal Communications Commission. The revenues are stratified by major source—local, toll, or miscellaneous—and deflated by specially prepared price indexes for these different services. The labor hours data are based on the Bureau's establishment payroll survey.

At one time, BLS published a productivity measure, the numerator of which was derived from the number of local and long-distance telephone calls, aggregated on the basis of revenue weights. This measure was discontinued in the mid-1950's because of concern that the labor input measure was not consistent with the output measure. For example, private line services, such as leased telephone lines, radio and TV transmission, teletype, and so forth, were reflected in employee hours but not in the output measure as defined. The same was true for calls between stations transmitted through private switchboards and directory services.

A different type of productivity index for the industry was initiated in 1973, with data back to 1951. The numerator of this measure was derived from annual revenue data stratified by major services and deflated, until last year, by price indexes furnished by American Telephone and Telegraph Co. Beginning in 1982, the BLS producer price index for telephone communications will be used to deflate the revenue data, and productivity indexes published for the industry since 1972 will be revised in accordance with the new procedure.

The BLS deflated revenue measure of the output of the telephone communications industry is fairly comprehensive. It includes revenues from private line services, which have grown in importance over the years, as well as those arising from the maintenance of private switchboards by telephone carriers. It also accounts for TV, radio, and computer data transmission by telephone industry facilities, and for directory services. However, certain measurement problems remain unresolved, including the unsatisfactory treatment of differences in intensity of the use of telephone equipment by customers. Intensity of use differences occur when revenue does not vary in proportion to the number of calls made because of flat charges, as in the case of local telephone service or WATS lines. Implicitly, the BLS output measure assumes that the maximum permissible usage takes place under any flat charge system used in the industry.

Business and personal services. In the area of business and personal services, which includes not only business, personal, and repair services, but also education, social services, and political organizations, BLS currently publishes only two measures of productivity, one for hotels and motels, and the other for laundry and dry cleaning services. These measures cover 13 percent of the total employment in the sector.

Because physical quantity information is not available for these two industries, output measures are developed using price-deflated value techniques. The techniques are similar to those described earlier, in that both revenues and employee-hour weights are used to aggregate the output indicators into a total industry output index.

On the input side, the hours of all persons are used as the measure of labor time. As in the trade sector, partners, proprietors, and unpaid family workers make up a significant portion of the work force. Currently, this group accounts for about 15 percent of all persons employed in laundries and 20 percent of the workers in hotels and motels.

BLS efforts to expand coverage in the business and personal service area have been hampered by two major problems. First, because many business service categories are quite broad, it is impossible to account adequately for changes in the mix of their component services. For example, we cannot publish a productivity index for automotive repair shops because there are almost no data available on the types of repairs that are made. The second problem is that not enough services are covered by the Consumer Price Index and, consequently, the deflated value of the output of many uncovered areas would have to be imputed.

Finance. In the finance area, BLS is developing a banking measure in terms of the three major services commercial banks render their customers—deposits, loans, and trust services. While banks also provide non-fund-using services, such as safe deposit and customer payroll accounting, lack of adequate data preclude deriving a measure for them. However, because the proportion of employees engaged in such services is very small, the overall output measure is little affected by the omission.

There has been much controversy over the years as to the appropriate measure of the output of banking. Some analysts have advocated a "liquidity" approach, others, a "transactions" approach. In the former, the banks are viewed as holders of money, and their output is equivalent to the net interest they receive on the volume of deposits held. This interest is the income depositors are willing to forgo to maintain deposits rather than in-

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vesting directly in assets less readily converted to cash, that is, the value to customers of the liquidity they enjoy from bank services. This approach can be extended to all types of savings accounts, on the principle that the forgone net interest is the value of the bank's services.

The other approach views banking output as a series of transactions; the volume of the bank's output is proportional to the volumes of the transactions handled. BLS has adopted this second approach for its productivity measure.

Accordingly, the final output of banks is defined as an array of depository, lending, and fiduciary services. Estimates of the number of transactions for each of the three service functions must be derived. Because no direct count of the number of transactions is available in many instances, estimates are made from data on the total value of transactions and surveys of average transaction amounts.

Deposit activity is measured in terms of the number of checks transacted and the number of time and savings deposits and withdrawals. (An electronic funds transfer is treated as a transaction on par with one involving payment by check.) The data for demand deposit activities are from Federal Reserve counts and official benchmark surveys. For time and savings deposit activity, the output measure is based on data published by the Federal Deposit Insurance Corporation and on the Functional Cost Analysis conducted annually by the Federal Reserve.

Lending services provided by banks are also measured in terms of units. As in the case of deposit and trust activity, BLS does not use banks' financial data to arrive at the component output measures. Use of such data would be highly misleading even if appropriate deflators could be found. For example, an increase in the aggregate deflated value of loans might simply reflect the making of a few large loans; similarly, a decrease might indicate the repayment of a few large loans, even as the number of small loans increased.

Twelve types of loan output are measured, for the most part using data generated by the Federal Reserve and the Department of Housing and Urban Development. Included in the loan output measure are commercial and residential mortgage loans; consumer loans; single-payment loans; credit card loans; and commercial and "other" loans. The number of loans can usually be derived by dividing the dollar value of total loans in a given category by the average face value of a loan. For the category of commercial loans, the actual number of loans extended has been available since the mid-1970's.

An experimental output measure for the trust department services of commercial banks is derived from the trend in the number of accounts. Trust accounts are stratified into five major categories, including benefit trusts, personal trusts, and estates.

After output estimates are developed for depository, loan, and fiduciary segments, they are aggregated to the industry level using employment weights.

SOME OF THE MAJOR PROBLEMS in developing labor productivity measures in the service activities and how BLS has tried to meet some of these problems have been highlighted above. Considerable work in this very important area has been conducted and the outlook for improvements in certain subareas is optimistic. For example, as price measures are improved and hours worked data become available, and as work in the area of government productivity measurement progresses, BLS will be able to provide a better picture of what is happening to productivity in more activities within the sector. Additional measures in communications, finance, insurance, and real estate, and business and personal services can and will be developed, and indexes for wholesale trade are very possible. However, there are severe conceptual as well as data problems in measuring productivity in such industries as education and social services and in the important field of medical services, and progress in these areas is expected to be much slower.

[1] In connection with work on multifactor productivity measurement, BLS is exploring the possibility of making adjustments for changes in work force composition.

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Productivity Change in the Bituminous Coal Industry, 1950-79

ROSE N. ZEISEL

Productivity in bituminous coal mining reached a peak in 1968-69 and declined every year thereafter except 1973 and 1978. From 1970 to 1979, output per employee hour declined 4.1 percent (annual average) and output per production worker hour fell 3.7 percent, as hours rose sharply and output only moderately. In contrast, productivity grew rapidly in the previous two decades. The high productivity growth rates of the 1950's reflected very sharp declines in hours, while in the 1960's, average hours dropped only moderately but output rose substantially.

Several factors contributed to rapid productivity growth in those 20 years. Of major importance was the diffusion of technological advances in deep mining, particularly continous mining, and proportionately greater output from more productive surface mines. Moreover, in that period, when coal's competitive position was poor, only the more efficient mines were still operating, raising the industry's level of productivity. Also, a high degree of labor-management cooperation resulted in a 20-year period free of contract strikes.

The increase in surface mining contributed greatly to productivity growth. Output per miner day in surface mines in the 1960's averaged 31 tons, compared with 14 in underground mining. And coal mined on the surface increased as a share of total output from 24 percent in 1950 to 38 percent in 1969. But in the 1970's, the productivity decline reflected declines in both surface mining and underground mining. Output per miner day in surface mines declined from 36 tons in 1969 to 25 tons in 1979; underground productivity fell from a peak of almost 16 tons in 1969 to 8 tons in 1979. Although many different explanations have been advanced to explain the decline, research by the Department of Energy and the Department of Labor indicates that environmental and safety regulations, periodic disruptions in production, and an increase in the number of less efficient mines and less experienced workers could be some of the factors.

Following enactment of the 1969 Coal Mine Health and Safety Act, additional employee hours in underground mines per unit of output were required to comply with the new regulations. Mining methods had to be changed, and the production process using continous miners was particularly affected. The diversion of some labor and capital to activities which did not increase output had an adverse effect on productivity. Although the impact of the legislation was less by the mid-1970's, greater enforcement probably continued to depress productivity growth. Similarly, the implementation of State reclamation laws could be one of the major causes for the productivity decline in surface mining. The impact of the Federal Surface Mine Control and Reclamation Act of 1977 on the productivity of surface mines will not be known until the act is more fully implemented.

Labor disruptions in the 1970's included three major contract strikes and many wildcat strikes. The practice of stockpiling before a strike, and catching up afterward, reduces efficiency.

In addition, smaller, less efficient mines entered the industry as coal prices rose in response to the oil embargo and to changing market conditions. From 1973 to 1976, the number of active deep mines increased by 40 percent. Smaller mines tend to have lower productivity, and their entry contributed to the decline in the mid-1970's. Also, a younger, inexperienced work force probably depressed productivity growth.

The decline in bituminous mining productivity contrasted sharply with trends in other sectors of the economy. From 1970 to 1979, output per employee hour in bituminous coal declined at an average annual rate of 4.1 percent, while in manufacturing it rose at a rate of 2.2 percent, and in nonfarm business, 1.3 percent. In contrast, from 1950 to 1970, productivity growth in coal mining had far exceeded growth in other sectors.

The decline also contrasted sharply with the trends in the coal industries of Europe and the U.S.S.R., although data are not fully comparable. From 1960 to 1978, while productivity in the U.S. coal industry declined by 23 percent, it increased in Poland and West Germany by 150 and 124 percent, respectively; in

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Belgium by 76 percent; and the United Kingdom by 48 percent. Nevertheless, the level of productivity in the U.S. industry in 1978 was still more than twice as high as in West Germany and Poland.

The productivity outlook for the U.S. industry is mixed. As the shift to capital-intensive western surface mines accelerates, productivity will be favorably affected. Western surface mines with thicker seams and less overburden are more productive than eastern surface mines. Also, with the shift West, the proportion of miners who are union-affiliated declines, which is likely to reduce the impact of work stoppages. On the other hand, State and Federal safety and environmental protection laws could have an adverse effect on surface mine productivity as they are more fully enforced.

Table 16. Output per miner day by method of mining, 1950-79

(Short tons)

Year	Total	Underground mining	Surface mining
1950	6.77	5.75	15.66
1951	7.04	6.08	16.02
1952	7.47	6.37	16.81
1953	8.17	7.01	17.73
1954	9.47	7.99	19.80
1955	9.84	8.28	21.17
1956	10.28	8.62	21.37
1957	10.59	8.91	21.87
1958	11.33	9.38	21.84
1959	12.22	10.08	22.94
1960	12.83	10.64	23.31
1961	13.87	11.41	25.29
1962	14.72	11.97	27.31
1963	15.83	12.78	29.30
1964	16.84	13.74	30.05
1965	17.52	14.00	32.76
1966	18.52	14.64	34.23
1967	19.17	15.07	35.87
1968	19.37	15.40	34.64
1969	19.90	15.61	36.00
1970	18.84	13.76	35.83
1971	18.02	12.03	35.88
1972	17.74	11.91	36.33
1973	17.58	11.66	36.67
1974	17.58	11.31	33.16
1975	14.74	9.54	26.69
1976	14.46	9.10	26.40
1977	14.84	8.69	26.59
1978	14.26	8.25	25.00
1979p	13.50	7.90	24.80

p = preliminary.

NOTE: Output per miner day represents total output for the year divided by the total number of miner days worked.

SOURCE: U.S. Department of Energy, Energy Information Administration.

Table 17. Productivity in coal mining, selected States, 1969 and 1978

State	Output per miner day			Percentage of total 1978 production from surface mines
	1969	1978	Change 1969-78	
	Short tons			
West:				
Montana	87.6	97.6	10.0	100.0
North Dakota	76.2	78.4	2.2	100.0
Wyoming	39.2	61.8	22.6	98.8
East:				
Illinois	29.0	13.9	−15.1	48.9
Kentucky	23.7	14.4	−9.3	56.2
Ohio	25.9	13.0	−12.9	71.1
West Virginia	16.0	8.5	−7.5	23.6

SOURCE: U.S. Department of Energy, Energy Information Administration.

Table 18. Output per employee hour in coal mining and selected sectors of the economy, 1950-79

(Index, 1967=100)

Year	Coal mining[1]	Private business sector[2]	Nonfarm business sector[2]	Manufacturing sector[2]
1950	37.7	61.2	67.2	65.8
1951	37.4	63.0	68.4	67.9
1952	39.2	64.8	69.7	69.2
1953	42.2	66.8	70.7	70.4
1954	48.4	67.9	71.8	71.4
1955	52.3	70.6	74.6	75.0
1956	54.1	71.5	75.0	74.4
1957	55.0	73.5	76.5	76.0
1958	59.9	75.4	77.9	75.6
1959	60.9	77.8	80.5	79.0
1960	65.5	79.0	81.2	79.8
1961	73.1	81.4	83.3	81.6
1962	78.6	85.1	86.9	85.2
1963	83.3	88.3	89.8	91.1
1964	88.8	91.7	92.9	95.6
1965	94.0	95.1	96.0	98.4
1966	98.2	98.0	98.4	99.8
1967	100.0	100.0	100.0	100.0
1968	102.2	103.3	103.2	103.7
1969	102.2	103.6	103.0	105.0
1970	98.9	104.4	103.2	105.0
1971	88.7	107.8	106.4	110.5
1972	82.4	111.5	110.1	115.7
1973	83.7	113.6	112.0	118.9
1974	80.9	110.2	108.6	113.0
1975	69.9	112.6	110.7	118.8
1976	68.5	116.6	114.6	124.0
1977	67.2	118.7	116.4	127.7
1978	71.5	119.3	116.9	128.2
1979p	65.9	118.3	115.7	129.2

[1] Based on hours of all employees.

[2] Based on indexes of real product and indexes of the hours of all persons engaged. The index of real product is based on a measure of value added in constant dollars and differs in concept from the physical output index for coal mining. Hours of all persons cover estimated hours of all persons engaged, including proprietors and unpaid family workers, and are based primarily on data from the BLS survey of business establishments.

p = preliminary.

SOURCE: Bureau of Labor Statistics.

Table 19. Underground coal mines, output per employee shift, United States and selected countries, 1960 and 1978

Country	Short tons		Percent change, 1960-78
	1960	1978	
United States	10.64	8.25	−22.5
Belgium	1.23	2.17	76.4
France	1.37	2.00	46.0
Hungary	.77	1.10	42.9
Netherlands	1.25	[1] 2.54	[1] 103.2
Poland	1.59	3.97	149.7
Spain	.67	1.43	113.4
United Kingdom	1.68	2.48	47.6
U.S.S.R.	1.70	[2] 2.52	[2] 48.2
West Germany	1.77	3.96	123.7

[1] 1974 data.

[2] 1976 data.

NOTE: Data are not strictly comparable among countries and may be used only as broad indicators of long-term trends. U.S. data are on a miner-day basis and include bituminous coal and lignite production. European and U.S.S.R. data are on an employee-shift basis and include bituminous and anthracite coal, but exclude lignite production except for data for France in 1960 in which lignite accounts for only a small percentage of total underground output. All data include surface operations of underground mines.

SOURCES: U.N. Economic Commission for Europe; U.S. Department of Energy, Energy Information Administration.

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Productivity in commercial banking: computers spur the advance

Nevertheless, output per employee hour paralleled the trend of the economy during 1967–80, with the annual rate of growth decelerating after 1973

HORST BRAND AND JOHN DUKE

The computer was among the major forces that spurred labor productivity advance in commercial banking in 1967–80. The computer also facilitated great increases in banking output. Labor requirements per unit of output, however, declined rather slowly during the period.

Output per employee hour in commercial banking rose at an average annual rate of 1.3 percent between 1967 and 1980—nearly the same as for the nonfarm business sector as whole (1.4 percent).[1] Data for a productivity measure for years prior to 1967 are inadequate, and none was calculated. Output over the period examined rose at a rate of 6.0 percent per year, employee hours, at a rate of 4.6 percent. The rise in banking productivity was associated with strongly expanding customer services and with advances in computer technology and their rapid diffusion throughout the industry. However, the spread of branch banking, while enhancing access to banking services, somewhat retarded productivity improvement, partly because scale economies became less favorable.[2]

The labor productivity trend in banking paralleled not only the long-term rate for nonfarm business but also the significant differences in rates of change between the 1967–73 and 1973–80 periods. Over the earlier span, productivity in banking rose at an average annual rate of 2.1 percent, compared with 1.9 percent for all of nonfarm business. Subsequently, the rate decelerated to 0.7 percent a year; for nonfarm business, to 0.9 percent.

Year-to-year swings in the productivity trend were pronounced, ranging from a drop of 6.9 percent in 1974 to a spurt of 6.1 percent in 1976. During the 12-year period, years of decline occurred 4 times, characterized by employment increases in the face of slowed advances (1969 and 1979) or declines in output (1974 and 1980). In such years, restrictive monetary policy (as in 1969 and 1979) or recession (as in 1974 and 1980) constrained the demand for funds. In years when productivity gains ran substantially ahead of the long-term trend average, strong cyclical recoveries or peaks in the demand for banking services occurred (as in 1971, 1973, 1976, and 1977).[3]

Measuring productivity

The labor productivity measure for commercial banking has been developed in accordance with the usual procedures of the Bureau of Labor Statistics for measuring changes in the relation between the output of an industry and the employee hours expended in producing that output. Commercial banking produces a variety of outputs, that is, services to the public. These services have been summed on the basis of weights which reflect —or are close substitutes for—labor requirements per unit of service. The output index was then divided by

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an index of employee hours for commercial banking, so as to obtain an index of output per employee hour, or labor productivity. The labor productivity measure for banking, then, measures the change over time in the ratio of the weighted output of the composite of services to the public to employee hours.

Output has been defined in terms of the three major banking activities: (1) demand deposit transactions, involving the crediting and debiting of checks written by the public, and time and savings deposits transactions, involving deposits upon and withdrawals from accounts held by the public; (2) lending for commercial, consumer, and real estate purposes; and (3) fiduciary, involving the administration of trusts and estates, and the purchase and sale of securities on their account.

The output measure for constructing the indexes of labor productivity in banking has been obtained from data on the quantity of these various services rendered by the banks to the public. As noted, in aggregating these services, the labor requirement per unit of each of the major categories of service in a base period was used as the basis for combining the dissimilar activities. Where labor requirement data were not available, proxies were employed.

The labor inputs used in constructing the productivity measure for commercial banking have been derived from BLS data for employment and employee hours, as reported by banking establishments on the basis of their payroll records. The labor input series, therefore, is an hours paid, rather than an hours worked, measure. No adjustment has been made for differences in skill, experience, or other factors of labor quality, data for such adjustments not being available.[4]

Output of banking services

Output of commercial banks as measured by BLS rose at an average annual rate of 6.0 percent between 1967 and 1980—twice as fast as output of the total private business sector. Sources of the strong growth were the boom conditions of the early seventies and the financial needs they generated; rapid increases in check transactions; relatively greater reliance by business on external funds; and continuously heavy demand for consumer and real estate credit. Also, commercial banks expanded their share of major types of such credit, as well as of time deposits. Moreover, they emphasized the retailing aspects of their services and consequently accelerated branching. Trust department functions also grew apace as pension and other employee benefit funds proliferated.

Banking output rose at a higher rate during the 1967–73 period (7.8 percent a year) than during the 1973–80 span (4.6 percent annually). Output was dampened considerably more in the recession that bottomed in 1975 than in 1970. Loan demand rose more rapidly prior to the 1975 recession than after. The rate of deposit transactions, especially demand deposits, also lost some momentum during the second half of the seventies.

Deposits. Periods of speedup and slowdown aside, demand and time deposits rose rapidly over the long term. The number of demand deposit transactions more than doubled. The velocity of transactions (measured by the number of times a dollar of debits is charged against deposits in a given period) nearly tripled.[5] Furthermore, the importance of demand deposits, a major source of lendable funds, declined in relation to the banks' total liabilities, from 43 percent in 1967 to 27 percent in 1979.[6] Intensifying demand deposit activity, especially during 1967–73, contributed to pressures to introduce such labor-saving procedures and equipment as electronic funds transfers (EFT).[7] Thus, according to a study conducted by the Federal Reserve Bank of Atlanta, the number of checks written by the public rose at an average annual rate of 7.2 percent during the first half of the 1970's and declined to a rate of 5.6 percent during the second half.[8]

In addition to the cash-economizing efforts by the public, evident from the tendency to hold relatively low check balances after the mid-sixties,[9] certain kinds of financial transactions have generated large amounts of account activity. For example, the number of shares traded on the New York Stock Exchange in the seventies averaged nearly 3 times the volume of the sixties. Such trading usually involves multiple funds transfers through the banking system. The number of commodity futures contracts traded on commodity exchanges nearly tripled between the first and the second half of the 1967–79 period.[10] Such trading also entails numerous funds transfers through the banks. The underwriting of stock and bond issues, usually by syndicates, which also rose in the mid- and late seventies, spells the pooling of lender funds and ultimate transfer to the borrower; "(Debits) totaling several times the amount of the financing involved may be recorded in this process. . . ."[11]

There were some developments that tended to retard the growth of transactions and check volume—for example, mergers, which cause book credit and debits to replace bank transactions; bank credit cards, which tend to consolidate individual payments; and the long-term trend towards the output of services relative to goods, making for fewer intermediate transactions. These tendencies were largely offset, however, by the upswings in manufacturing and construction, which result in numerous intermediate transactions.

Time deposits generally expanded rapidly following the progressive liberalization of permissible rates under the Federal Reserve's Regulation Q. Liberalization strengthened the banks' position in retaining and attracting funds which would otherwise have been invested elsewhere. Savings and other time deposits held at the commercial banks by individuals, partnerships,

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and corporations climbed 106 percent between 1968 and 1980, while demand deposits rose 52 percent. Time deposits accounted for 60 percent of total commercial banking deposits in 1980, as against 54 percent in 1968 (and 35 percent in 1960). Some observers have noted that, in view of such technological advances as electronic funds transfers, the distinction between time and demand deposit accounts has become less significant.[12]

Loans. Expansion of loan output was another source of output growth. The rate of increase of loan output had begun to accelerate prior to 1967, and some of the underlying factors—for example, the emphasis on retail banking—have, of course, a long history. Loan volume being highly susceptible to the impact of the business cycle and of monetary policy on the demand for funds, year-to-year movements proved to be much more erratic for lending than for the volume of deposit transactions. The long-term trend was influenced by the increasing propensity of business to contract for term loans (that is, loans with maturities of more than 1 year); the continued accent upon retail banking; and banks' growing share of mortgage and consumer credit.

Nonfinancial business became more dependent upon funds raised in credit markets than it had been earlier (when corporations had relied more heavily upon internally generated funds). Between 1967 and 1980, the ratio of credit market borrowing by nonfinancial business to its capital expenditures averaged 44 percent, compared with 29 percent for the earlier sixties. The composition of commercial and industrial loans shifted toward term loans, indicating that banks were financing a growing proportion of the plant and equipment outlays as well as of inventories of nonfinancial business.[13]

Banks also stepped up their consumer credit operations. Here, too, growth, of course, originated in earlier years. The share of disposable income devoted to installment borrowing began to rise in the early sixties; at 16 percent in 1967, it continued to rise gradually to 20 percent in 1979. (In 1980, a recession year, the ratio dropped.) Furthermore, the commercial banks expanded their share of holdings of total consumer credit outstanding from 42 percent in 1967 to 49 percent in 1973, remaining at about that level from then on. This gain was linked in part to a shift away from retail store credit, together with growing consumer acceptance of bank credit cards and check credit.[14]

Growth in banks' real estate loans was in large part tied to the expansion in residential and commercial construction of the early seventies and to the strong recovery of both after their slump in the mid-seventies. Banks also captured a larger share of total mortgage holdings, rising from 19 percent in 1967 to 25 percent in 1979 (as the share of insurance companies, in particular, declined). Growth in this area of lending was in recent years also strongly influenced by household borrowing against equity in existing homes.[15]

Table 1. Productivity and related indexes for commercial banking, 1967–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1967	83.8	52.2	62.3	63.0
1968	85.3	56.3	66.0	66.7
1969	84.0	60.0	71.4	72.0
1970	85.5	64.5	75.4	76.6
1971	88.6	69.1	78.0	79.0
1972	90.3	74.3	82.3	82.9
1973	95.9	83.2	86.8	87.5
1974	89.8	82.9	92.3	92.6
1975	90.0	84.6	94.0	94.2
1976	95.0	91.8	96.6	96.8
1977	100.0	100.0	100.0	100.0
1978	100.7	105.4	104.7	104.9
1979	98.5	108.1	109.7	110.5
1980	92.7	106.1	114.5	115.7
1967–80 average annual rate of change (in percent)	1.3	6.0	4.6	4.5

Trust services. Long-term gains in the trust department output of commercial banks have been associated with the growth in the number of fiduciary accounts and the activity these accounts generate.

Between 1968 (when pertinent data first became available) and 1980, the number of such accounts rose 54 percent.[16] The increase was linked to a more than threefold rise in employee benefit accounts, reflecting the spread of corporate retirement and other employee benefit plans, as well as of pension plans initiated by self-employed persons (Keogh plans).[17] The number of personal trust accounts rose by two-thirds; they still constitute the single most important trust department service, representing more than three-fifths of bank-administered trust accounts. Their rise has in part been related to the desire to shelter current income from taxation, notably as inflation has tended to push incomes into more heavily taxed brackets.[18]

Employment and changing skills

Employment in commercial banking, currently numbering 1.5 million persons, rose 84 percent between 1967 and 1980, or at an average annual rate of 4.5 percent. Average weekly hours tended to decline somewhat, from 37.1 in the first 5 years of the period to 36.5 since then—owing chiefly to the employment of more part-time workers.[19] In no year did aggregate employee hours decline, but their most vigorous rise occurred over the first half of the review period (5.6 percent annually). That high rate was not equaled even during the cyclical recovery following the 1975 slump. From 1974 to 1980, gains averaged 3.8 percent annually.

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Nonsupervisory jobs accounted for nearly four-fifths of commercial banking employment in 1980. Of these jobs, office and clerical positions again accounted for four-fifths of employment in the top 100 banks, or 37 percent of total banking employment in 1980. Women staffed 85 percent of these jobs and about one-third of all officer positions. They accounted for two-thirds of banking personnel in 1980, compared with 41 percent of all payroll employment.[20] The prevalence of relatively low-skilled jobs in banking is reflected by the ratio of average hourly earnings in the industry to average hourly earnings in the private economy. Despite the growth of positions in computer programming and systems analysis, that ratio has tended to decline, from 0.87 in the sixties to 0.73 in 1980.

Supervisory jobs in commercial banking have increased in both absolute and relative terms. Such jobs accounted for 23 percent of employment in 1980, as against 17 percent in 1967, an increase of 144 percent. Nonsupervisory jobs rose 65 percent. The ratio of nonsupervisory to supervisory employees thus dropped from 5:1 in 1967 to slightly more than 3:1 in 1980. The increase in supervisory workers was in large part linked with the expansion of branching and the attendant needs for managerial personnel. It was also related to a rise in the number of loan officers, especially for installment loans, and of credit analysts, who are frequently charged with supervisory responsibilities in addition to their regular work.

Skills needed by commercial banking employees have changed considerably, even during the relatively short period examined here. For example, the number of bookkeeping operators has dropped by more than one half since 1969 (and by more than 90 percent since 1960)—owing to the spread of electronic bookkeeping machines and computers, which require substantially fewer operators.[21] Also, tellers have tended to become less specialized as branch banking has spread. The six usual teller classifications—note, commercial-savings, commercial, savings, vault, and all-round—have in many banks been reduced to one all-round teller classification. The practice of classifying tellers by commercial or saving transactions has been declining.[22]

Most bank employees perform tasks related mainly to the banks' depository functions and loan administration. A high school education is generally considered adequate preparation for entry level jobs. Bank officers, on the other hand, usually supervise the various financial and customer services. Loan officers, in particular, are expected to be knowledgeable about the industries from which the individual bank draws its customers and to be sensitive to the often unique problems customers present—problems which frequently require handling on a personal basis. Officers usually have a college degree or an MBA.[23]

The labor inputs of commercial banks thus vary widely in terms of education, training, and skill complexity. Also, wide differences exist between the tasks that can be automated and tasks that cannot be, with the work of loan officers being least susceptible to standardization and automation. However, even in this area, a growing number of supplementary tasks have been computerized.[24]

Fixed investment and technology

Between 1967 and 1979, banks' fixed capital, including structures, furniture, and equipment, rose by a factor of three, while the stock of fixed nonresidential capital in the private business economy as a whole rose by a factor of nearly four.[25] Price indexes to deflate the banks' physical capital stock are not available, so no firm estimate of movements in constant-dollar value can be offered. When the deflators for the total capital stock of business are applied to that of the banks, a rise of about one-third in real terms would result.

About 40 percent of the banks' spending on fixed capital went for equipment and furniture during the review period. In 1980, roughly half of the banks' expenditures for fixed capital other than structures was spent on computers and computer equipment.[26] Fixed capital per employee in commercial banking, at about $16,000 in 1979, ran at three-fifths of the comparable figure for the business economy.[27]

Computer breakthrough. At the root of equipment spending has been the transformation of technology by electronic data processing (EDP). While banks progressively mechanized their routine operations throughout the forties and fifties, the resulting efficiencies improved but gradually. Some students of the field, in fact, attributed these efficiencies more to the specialization of labor and economies of scale in the industry than to mechanization.[28] A 1960 study by the Federal Reserve Bank of Philadelphia stated, "Since World War II, banks apparently have expanded operations more by hiring extra people than by using better equipment."[29] According to the study, the technology used in banks had scarcely changed during most of the first half of the 20th century. The same basic types of cash registers, punched card tabulators, billing and duplicating machines, and check signing equipment found in banks in 1914 were still the mainstay of banking technology at the end of World War II.

Although computer developments during the fifties embodied the principle of machine readability, it was the introduction of magnetic ink character recognition (MICR) in 1958 that made the breakthrough of electronic data processing in banking possible. The computer became an indispensable and major factor in improving banking productivity. Moreover, computer technology

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has rapidly spread throughout the industry. The first bank automation survey conducted by the American Bankers Association in 1963 showed only 7 percent of all commercial banks to be users of on-premise or off-premise computers. By 1968, 49 percent were users, and in 1980, when the latest available survey was conducted, 97 percent were. The pressures of cost efficiencies, organizational changes, and competition had reduced the proportion of surveyed banks without plans to automate from 84 percent in 1963, to 42 percent in 1968, to virtually nil in 1980.[30] While the larger banks—those with $100 million-plus in deposits—generally maintain their own computer operations, smaller banks have increasingly used their correspondent relations with the larger banks to gain access to computers. As of 1980, 26 percent of all banks operated on-premise computers, while 71 percent used off-premise computers, mostly at correspondent banks.[31] Thus, size of bank, as measured by the dollar value of deposits, does not appear to have seriously inhibited the diffusion of EDP technology in the industry.

The computer has had its greatest impact upon the deposit function, particularly upon check handling. Its full potential, however, is only beginning to be realized, inasmuch as optimally most payments transfers could be processed electronically, that is, without checks. But only a small proportion of payments is so processed at present. Each check is, in effect, "a special piece of currency, created for one transaction only, that has to pass through complex and repeated identification, verification, accounting, and sorting operations before it is retired."[32] Until the mid-seventies, the enormous and steadily growing volume of checks (estimated at 32 billion in 1979) was expected to become too expensive to handle, even by computer. But evolving technology has expanded the check-processing capacity of computers, such that they are thought to be able to "handle any conceivable number" of checks.[33]

The currently most advanced (or "third-generation") computer has a built-in reader-sorter processing capacity of 120,000 checks per hour. Manual reading and sorting of checks, which for many years has involved some machine processing such as high-speed readers, averages 1,200 to 1,400 checks, so that computer use for this phase of the check-handling process represents "order of magnitude" reductions in labor requirements.[34] For other phases of check-handling, comparable productivity advances have not been attained, although so-called rejects or exception items, which in earlier years required laborious interbank correspondence, have come to be processed with great efficiency thanks to cooperative agreements. According to surveys by the Bank Administration Institute, the average labor requirements for all phases of handling checks were reduced by well over one-half between 1970 and 1979 among surveyed banks, mainly because of computerized reading and sorting of checks and more efficient handling of exception items.[35]

In loan operations, EDP has been used for information retrieval, as well as in the administration and bookkeeping operations of such loan categories as installment loans. Credit information, mortgage servicing, bank credit card billing, and accounting have also been among major computer applications. The proportion of personnel in installment loan operations has tended to decline, but the available data do not clearly point to improved productivity in this area of banking. Staff employed in handling bank credit cards—also a type of consumer credit—has expanded in recent years.[36] Business loan operations, which require a comparatively small proportion of bank personnel, have remained relatively labor-intensive—largely owing to their specialized nature and the need for maintaining close customer contact. Even here, however, the computer is playing an increasing role. It is used to provide up-to-date credit analyses and to serve as a bankruptcy predictor. For the larger banks, it makes credit information on a worldwide basis rapidly available. It also facilitates the collection and arraying of data to meet the requirements of regulatory authorities, a task that is otherwise highly labor-intensive.[37]

Computer technology has also contributed to improved productivity in trust departments. It has been primarily applied to information retrieval for purposes of controlling individual accounts.[38] But it has been increasingly used as well in stock trading by trust departments for customer accounts. With trust departments holding the largest share of assets in stocks (49 percent in 1980 by value), such trading accounts for the major part of their activity. The basis of automated stock trading has been a numbering system first devised by the American Bankers Association's Committee for Security Identification Procedures in 1968. The use of committee numbers on stock certificates was mandated by the Securities and Exchange Commission in 1971. This and similar systems have tended to standardize stock identification and have contributed to the transfer of stock without the physical handling of stock certificates. These certificates are "immobilized," that is, they remain in central depositories. Costly errors and redundant bookkeeping entries have been nearly eliminated when trust departments have adopted the technology on which the bankers' stock transfer system is based.[39] Payments and credits involving stock transfers likewise use the system. Relative to output, trust department personnel requirements have been evidently reduced as a result of these and other computer applications.[40]

Electronic Funds Transfer. Potentially the most important use of the computer in banking remains electronic

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funds transfer (EFT). Although the technology for EFT has existed for nearly two decades, its acceptance by the public has been comparatively slow. Also, a large part of the costs of the check collection system and of demand deposit transactions was absorbed by the Federal Reserve and the banks, rather than passed on to users. Nevertheless, EFT has been increasingly adopted by the banks since the mid-seventies. Competition among financial institutions, as well as the developing cost advantages of EDP over conventional transfer activities, are likely further to speed adoption of EFT technology.[41]

EFT has been increasingly applied in interbank settlements through automated clearinghouses and in basic kinds of teller operations involving customer services, such as deposits and withdrawals, direct deposit of payrolls or other recurring payments, direct bill payment, and transfer of funds from savings accounts to demand deposit accounts and *vice versa*. Point-of-sale terminals, linking merchants with a network of local banks, have also been spreading, although their acceptance and use have remained limited.[42]

Automated clearinghouses have spread rather gradually, although they have not replaced the conventional clearinghouse process as they handle only paperless credit and debit entries between banks. Originating in San Francisco in 1972, automated clearinghouses currently link an estimated 14,000 financial institutions and their offices; they process an estimated 300 million items annually.[43] This number represents but a small fraction of the total number of checks drawn on banks other than the payor's own bank, but it is expected that automated clearinghouses will account for a rising proportion of all items in the clearing process. Among reasons for this expectation have been the success of the direct deposit of social security payments and of a growing number of public and private payrolls; the associated savings in mailing costs; less work incident to replacing lost checks, and the cost pressures linked to the handling of paper items (which despite the increasing efficiency of the process has been more and more complemented or replaced by EFT).[44]

Teller machines. Automated teller machines spread rapidly in the late seventies. Providing customer access by means of a magnetic-stripe bank card and unique identification entered upon a keyboard, the machines receive deposits and payments and dispense cash. Twenty-four hour access is a frequent feature, enhancing customer convenience and reducing waiting lines. Thus, automated teller machines in effect extend banking hours, although banks also view them as "peaking" equipment, helping to reduce lobby traffic during peak hours of business. The machines substitute capital for labor, but for many medium- and smaller size banks, the relatively high fixed costs of the equipment are not offset by savings in labor costs at current volumes of business—a factor that tends somewhat to retard the diffusion of the devices.[45] According to one authority, 19,000 automated teller machines were in use at the end of 1980, each averaging about 4,600 transactions per month, more than 2.5 times the volume 4 years earlier—signifying rapid consumer acceptance of this technology.[46]

The banks have also installed much technologically advanced equipment other than computers and teller machines. For example, word-processing equipment is now being operated in four-fifths of the larger and two-fifths of the smaller banks. Optical character recognition equipment—used, for example, in the processing of credit card charge slips, checks, and direct bill payments—has likewise been installed in most larger banks.[47]

The growth of branch banking

The number of commercial banking firms barely rose 5 percent between 1967 and 1979. But the total of banking offices increased 62 percent, mostly reflecting a doubling in the number of bank branches, and a continuing shift of offices towards the suburban population centers of metropolitan areas. The average population served per bank office declined from nearly 6,000 persons in 1970 to 4,400 in 1980.[48] The decline suggests that banking services became more widely and conveniently available to the public. Current-dollar disposable income per capita nearly tripled during 1967–80 (as did personal consumption expenditures), and households generated an expanding volume of banking business, supporting the spread of branch banking.

Most banks are comparatively small. Those holding total deposits of up to $50 million represent 79 percent of all commercial banks, but in 1979 accounted for only 15 percent of total deposits. Smaller banks usually maintain correspondent relations with the larger banks, and this relation amounts to a "form of multi-office banking."[49] Some of the efficiencies or customer utilities associated with large-scale banking are likely, therefore, to be shared throughout most of the industry.

The larger banks, however, are dominant. The share of deposits held by the Nation's largest banks—those with deposits of $500 million or more—was 62 percent in 1979. These banks constitute little more than 2 percent of total banks. Moreover, in metropolitan areas, the two largest banking organizations usually hold between 55 percent and 67 percent of deposits (the ratio tends to be lower in unit banking States, higher in statewide branching States).[50] Adoption of computer technology has been shown to be closely associated with bank size, as well as with holding company affiliation.[51]

As might be expected, banking employment is also concentrated in the bigger banks. Banks holding $500

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million or more in deposits employed 56 percent of all banking personnel in 1979. Banks with less than $100 million in total deposits—89 percent of all banks—employed 27 percent of all personnel.[52]

Among changes in the competitive pattern of financial institutions that have affected banks has been the spread of NOW (negotiable order of withdrawal) accounts at thrift institutions; their effect on the share of time deposit accounts at commercial banks, however, cannot be assayed yet. In some other areas, the role of commercial banks has been eroded. More efficient corporate cash management, spurred by high interest rates and advanced information technology, has diminished the relative importance of demand deposits. Also, commercial banks have evidently been unable to expand their share of credit cards (15 percent of 600 million outstanding cards in recent years). Also, business and consumer credit extended by very large department store chains, automotive companies, farm equipment makers, and EDP manufacturers grew in importance until the early seventies, although their share of financial assets has apparently stabilized since.[53]

Outlook for the industry

The diffusion of EFT is likely to help improve labor productivity in commercial banks in the years ahead. During the late seventies, doubts about its widespread acceptance were expressed in some quarters.[54] Resistance by consumers to abandoning payment by check and their fear of loss of control over balances were cited as two reasons. Regulatory questions concerning the off-premises installation of automated teller machines were another. Also, smaller banks were believed to have opposed EFT because of possible competition from big money-center banks. These obstacles to the diffusion of EFT have so far been only partly overcome. However, cost considerations seem likely to compel its more rapid adoption. To illustrate, in a study of the benefits of electronic government payments done in 1977, the Federal Reserve found the costs of EFT to run nearly two-thirds below the costs of processing checks.[55] The ratio has lessened since then, for the scale economies of EFT have continued to improve, and processing and mailing costs of checks to rise.

Direct deposit of payrolls and of other recurring payments, and direct bill payment will likely also expand, partly owing to the costs of float, which banks must assess as an explicit cost under recent legislation, as well as because banks must offset the cost of handling checks against interest on demand deposits (where such interest is offered). Thus, resistance to EFT is likely to lessen as costs of processing paper items rise—speeding its diffusion.

Continued technological advances and the labor savings expected from them will probably also arise from intensified competition by nonbank financial institutions. Thus, money market funds have come to compete with time and saving deposits for both the small and large investor's dollar, and this, too, may contribute to restricting commercial banks' output growth.[56] Also, more than 80 percent of all household and virtually all business firms had checking accounts in 1977, so that the expansion of banking services from including additional households is quite limited. A partially offsetting factor may be a continued rise in cash withdrawals from automated teller machines, which are believed to be smaller and more frequent than withdrawals by cashing checks.[57] The convenience in the use of banking services made possible by the machines may encourage the banks to adopt product lines similarly appealing to customer convenience.[58]

With the spread of EFT, and other computerized and automated transactions, banks' labor requirements per unit of output are bound to continue to decline. Moreover, new branch staffing needs should be decreasing, partly because of the technological developments discussed, partly because of the already low level of population served per branch, and the consequent abatement in the number of new branches opened. Hence, commercial banks will probably become less important as a source of added employment in the years ahead—also indicated by BLS projections to 1990, which imply a slower rate of banking employment growth than over the past decade.

[1] Commercial banks are establishments primarily engaged in accepting deposits from the public and making loans and investments. They are designated as No. 602 in the Standard Industrial Classification (SIC) Manual of the Office of Management and Budget. The industry is part of SIC 60—banking, which also includes Federal Reserve Banks, mutual savings banks, trust companies not engaged in deposit banking, and establishments performing functions closely related to banking. Nonbanking subsidiaries of bank holding companies are not included; they are separately classified by primary activity. See *Federal Reserve Bulletin*, December 1972. Commercial banks account for approximately 90 percent of the employment of the total SIC 60 group.

A detailed description of banking output and of the procedures followed in measuring banking productivity, output, and employee-hours, as well as the weighting scheme underlying the output measure, is available upon request.

[2] There is wide agreement among industry observers that scale economies in banking have declined with the spread of branching—that is, more resources, including labor inputs, are required per unit of output. Among definitive studies are *Costs in Commercial Banking*, by Frederick W. Bell and Neil B. Murphy (Federal Reserve Bank of Boston Research Report No. 41, April 1968), and "Economies of Scale and Marginal Costs in Banking Operations," by George J. Benston (*The National Banking Review*, June 1965), reprinted in that report. Industry observers confirm that the tendencies analyzed in these works have persisted.

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[3] Professor Charles F. Haywood of the College of Business and Economics, University of Kentucky, interprets the swings in commercial banks' labor productivity as follows: ". . . (At) the beginning of an upswing, banks have some slack in manpower and can increase output somewhat without increasing the rate of new hires. At some point in the upswing, the rate of new hires has to be increased. By the time these new hires are in place, the upswing in the economy is near its end and recession soon follows. There may also be some variation in labor turnover rates related to cyclical variation in the economy that affects input-output relationships in banks . . . (As) turnover rates are high in banking, cyclical variation in such rates could have significant effects on productivity." Communication to the BLS Office of Productivity and Technology.

[4] Among authorities upon whose conception of the banks' functions and output the BLS definition is partially based is Professor Donald Hodgman of the University of Illinois. Hodgman has viewed banking activity as consisting of a bundle of services, grouped into three categories: management of the national payments mechanism; intermediation between borrowers and lenders; and specialized financial services (of which trust activities are by far the most important ones). See Donald Hodgman, *Commercial Bank Loan and Investment Policy* (Urbana, University of Illinois, 1963), p. 165 ff; and John Gorman, *Comment*, "Real Output and Productivity of Banks," in Victor R. Fuchs, ed., *Production and Productivity in the Service Industries* (New York, National Bureau of Economic Research, 1969), p. 189 ff.

[5] See *Banking and Monetary Statistics, 1941–1970*, Board of Governors, Federal Reserve System, p. 321 ff., for a detailed explanation of the turnover rate of demand deposits.

[6] These and other data on commercial banks' shares in financial assets or liabilities were calculated from data from *Flow of Funds Accounts* (Board of Governors, Federal Reserve System), various recent issues.

[7] "Earliest concern with the payment system was rooted in the fear that growing check volumes posed a threat to the continued satisfactory performance of the system. Studies sponsored by the Federal Reserve System and by several national associations of commercial banks in the 1960's placed virtually their entire emphasis on two areas: measuring the national check volume, the pattern of the flows of checks into and through the banking system, and check processing costs; and offering technical and economic feasibility assessments of electronic alternatives of the time to check clearing and collection system. The emphasis throughout was on the use of electronic means to replace checks, or to reduce check handling, through systems created and cooperatively operated by groups of commercial banks, with a key role implied or advocated for the Federal Reserve System." Edwin B. Cox, "Developing an Electronic Funds Transfer System: Incentives and Obstacles," *The Economics of a National Electronic Funds Transfer System*, proceedings of a conference held in October 1974 (Federal Reserve Bank of Boston), p. 16.

[8] *A Quantitative Description of the Check Collection System*: Vol. 1, a report of research findings on the check collection system, cosponsored by the American Bankers Association, Bank Administration Institute, and Federal Reserve System (Atlanta, Ga., Federal Reserve Bank, 1981), p. 1.

[9] See also Bryan Higgins, "Velocity—Money's Second Dimension," *Monthly Review*, Federal Reserve Bank of Kansas City, June 1978, and George Garvy and Martin R. Blyn, *The Velocity of Money* (New York, Federal Bank of New York, 1970), p. 69.

[10] New York Stock Exchange, *Fact Book 1980*, and U.S. Commodity Futures Trading Commission, *Annual Report* (1980).

[11] Garvy and Blyn, *The Velocity of Money*, p. 43.

[12] "Increasing Competition between Financial Institutions," *Economic Perspectives* (Federal Reserve Bank of Chicago), May/June 1977, p. 23 ff.

[13] Term loans rose from 40 percent of total commercial bank loans in 1967 to 44 percent in 1973 and 48 percent in 1978.

[14] For some reasons why banks attempt to expand their credit card systems, see "EFT in the United States, Policy Recommendations and the Public Interest," The Final Report of the National Commission on Electronic Fund Transfers (Washington, October 1977), p. 134. See also *Bank Credit-Card and Check-Credit Plans* (Board of Governors, Federal Reserve System, July 1968). Banks' adoption and operation of credit plans of their own has had significant implications for their output: although credit cards result in consolidation of payments and, therefore, reduce the number of check transactions, they generate sales drafts which must be cleared through merchant's deposit accounts. Thus, they augment "the paperwork burden to the extent that (they replace) cash in a retail transaction" (p. 63.)

[15] David F. Seiders, *Mortgage Borrowing Against Equity in Existing Homes: Measurement, Generation, and Implications for Economic Activity* (Board of Governors, Federal Reserve System, 1978), Staff Economic Studies 96.

[16] See *Trust Assets of Banks and Trust Companies* (Board of Governors, Federal Reserve System; Federal Deposit Insurance Corporation; and Office of the Comptroller of the Currency), 1980 and earlier years.

[17] Indicative of the increase in corporate pension and welfare plans is the rise in the number of such plans reported by the U.S. Department of Labor. As of January 1, 1970, 157,400 such plans were reported, the number rising to 554,000 by 1977. The bulk of the assets in which the plan administrators invest consists of stocks and bonds. See *Welfare and Pension Plan Statistics, 1967, 1969, and 1971* (U.S. Department of Labor, Labor-Management Services Administration), and information from LMSA.

[18] Interview with a banking representative.

[19] Part-time workers accounted for almost one-sixth of all nonsupervisory office workers in surveyed commercial banks in 1980, up from one-eighth in 1976, according to *Industry Wage Survey: Banking, February 1980*, Bulletin 2099 (Bureau of Labor Statistics), p. 3.

[20] Equal Employment Opportunity Commission Summary Statistics, Top 100 Full Service Banks.

[21] *Technological Change and Manpower Trends in Six Industries*, p. 51, and *Industry Wage Survey: Banking*, p. 4.

[22] *Industry Wage Survey: Banking*, p. 4.

[23] See *Banking and Insurance Occupations*, Bulletin 2075–7 (Bureau of Labor Statistics).

[24] David M. Coit, "Automated Financial Analysis: A New Tool for Commercial Lending," *The Journal of Commercial Bank Lending*, March 1977.

[25] *Assets and Liabilities of all Commercial Banks in the United States, Annual Report for 1980 and Earlier Years* (Washington, Federal Deposit Insurance Corp.).

[26] Information on the average annual expenditures per bank for computer equipment, 1980–82, is provided in table 224 of *National Operations/Automation Survey, 1981* (Washington, American Bankers Association).

[27] The prices for computer hardware, as well as for calculating and accounting machinery, widely used by the banks, rose much more slowly than producer durables prices generally or tended to decline over part or all of the review period. See Robert B. Archibald and William S. Reece, "Partial Subindexes of Input Prices: The Case of Computer Services," *Southern Economic Journal*, October 1979, pp. 528–40. The authors show that second generation computers, manufactured for large business uses by IBM, dropped in price by 85 percent between 1970 and 1975. Reasons for the drop are discussed by them. At present, the BLS imputes movements in the value of computer hardware to the office and store machines and equipment group.

[28] See Bell and Murphy, *Costs in Commercial Banking*, discussion in chapter VII, p. 105 ff.

[29] "How Banking Tames its Paper Tiger," *Business Review* (Federal Reserve Bank of Philadelphia), June 1960.

[30] See *National Operations/Automation Survey 1981* (Washington, American Bankers Association), p. 7.

[31] *Ibid.*

[32] John E. Sheehan, "Higher Productivity Demand Deposits," in *The 1972 National Operations and Automation Conference Proceedings* (Washington, American Bankers Association), p. 363.

[33] John S. Reed, executive vice president of Citibank, quoted in "Electronic Banking: A Retreat from the Cashless Society," *Business Week*, Apr. 18, 1977. See also Sanford Rose, "Checkless Banking is

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Bound to Come," *Fortune*, June 1977, p. 118 ff.

[34] Information from Bank Administration Institute and Federal Reserve.

[35] See *1979 Survey of the Check Collection System* (Park Ridge, Ill., Bank Administration Institute, 1980).

[36] *Functional Cost Analysis, 1979 Average Banks.* Based on data furnished by 751 participating banks in 12 Federal Reserve districts. Computer processing of bank credit card transactions has remained similar to that of checks and therefore is technologically not as advanced as computer processing of transactions under credit cards issued by the big oil companies, where optical character recognition has been part of the computer operation. (Conversation with ABA representatives.)

[37] "Automated Financial Analysis."

[38] *Third Trust Operations and Automation Workshop, 1972 Proceedings* (Washington, American Bankers Association). See also *The Bottom Line: Proceedings, 1976 National Trust Operations and Automation Workshop, New York, March 21–24, 1976*, remarks by William Schladebeck, p. 216 ff.

[39] *Third Trust Operations—Proceedings*, p. 58.

[40] H. Russell Morrison, "CUSIP Report—Beyond Apr. 1, 1972," *Third Trust Operations & Proceedings*, p. 58.

[41] See N. Sue Ford, "Electronic Funds Transfer: Revolution Postponed," *Economic Perspectives* (Federal Reserve Bank of Chicago), November–December 1980, p. 16 ff. Competition between different types of financial institutions has been fostered by high interest rates together with NOW (negotiable order of withdrawal) accounts at thrift institutions, and of share drafts at credit unions. Such instruments have been authorized on a national basis by the Deregulation and Monetary Control Act of 1980. A detailed analysis of this law may be found in *Economic Perspectives*, September–October 1980, p. 3 ff.

[42] Ford, "Electronic Funds Transfer," p. 18.

[43] Haywood, communication to the BLS. See Philip E. Coldwell, "The ACH in Perspective" (*Remarks at the 4th Annual NACHA Surepay Conference, Houston, Tex., Mar. 13, 1979*), p. 3.

[44] Ford, "Electronic Funds Transfer," p. 16. See also Carl M. Gambs, "Automated Clearinghouses—Current Status and Prospects," *Economic Review* (Federal Reserve Bank of Kansas City, May 1978), p. 3 ff.

[45] ATM's often "substitute . . . for a more costly full-service brick-and-mortar branch." Haywood, communication to BLS. Another observer has stated that, "The ATM also reduced the need for tellers, lowering not only the salary cost to the bank, but also of employee benefits and pension plans." Ford, "Electronic Funds Transfer", p. 17. See also David A. Walker, *An Analysis of Changes in EFTS Activity Levels, Costs and Structure in the U.S.: 1975 to 1977* (Washington, Federal Deposit Insurance Corp.), Working Paper No. 77–3, especially p. 7.

[46] Linda Fenner Zimmer, "ATM Acceptance Grows, Builds Customer Base for Other EFT Services," *The Magazine of Bank Administration*, May 1981, p. 31. Cited in *Statistical Information on the Financial Services Industry* (Washington, American Bankers Association, 1981), p. 107.

[47] American Bankers Association, 1978 Survey, *op. cit.* On the productivity effects of such equipment, see also David Cockroft, "New Office Technology and Employment," *International Labour Review*, November–December 1980, p. 689 ff.

[48] *Statistical Information on the Financial Services Industry*, p. 89.

[49] Carter H. Golembe, "Growth of Bank Holding Companies," in Herbert V. Prochnow, ed., *The Changing World of Banking* (New York, Harper & Row, 1974), p. 23.

[50] "Recent Changes in the Structure of Commercial Banking," *Federal Reserve Bulletin*, March 1970, p. 207.

[51] See Charles F. Haywood, "Regulation, Technological Change and Productivity in Commercial Banking," in *Productivity Measurement in Regulated Industries* (New York, Academic Press, 1981), p. 300–01.

[52] Based on unpublished data of the Federal Deposit Insurance Corporation.

[53] Will R. Sparks, *Financial Competition and the Public Interest* (New York, Citicorp., 1978), p. 23, also pp. 16, 17.

[54] Reed, "Electronic Banking." See also William Ford, *The Payments System of the 1980's*, presented at the Second Annual Shared EFT Systems Conference, Atlanta, Ga., Feb. 5, 1981 (Federal Reserve Bank of Atlanta).

[55] *Costs, Savings and Benefits of Electronic Government Payments* (Unpublished study by the Division of Federal Reserve Bank Operations, Board of Governors, Federal Reserve system, June 1977).

[56] See "The Changing Environment for Banking," an address by J. Charles Partee, before the American Institute of Certified Public Accountants Annual National Conference on Banking, Capitol Hilton, Washington, D.C., Dec. 4, 1980. Also, "America's New Financial Structures," *Business Week*, Nov. 17, 1980, p. 138 ff.; and Constance Dunham, "The Growth of Money Market Funds," *New England Economic Review* (Federal Reserve Bank of Boston), September–October 1980, p. 20 ff.

[57] On the factors influencing the evolution of EFT and the check payments system, see *The Payments System of the 1980's*, op. cit.

[58] Some nonbank services built into ATM's are noted in "Diebold's Shift to Automated Tellers Works," by Margaret Yao, *The Wall Street Journal*, July 15, 1982, p. 45.

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Productivity and new technology in eating and drinking places

Labor-saving techniques for preparing meals, the rapidly expanding fast food chains, and a decline in the number of drinking places have altered output and hours in the industry

RICHARD B. CARNES AND HORST BRAND

Productivity in eating and drinking establishments[1] rose at an average annual rate of 1.0 percent between 1958 (when adequate data became available) and 1976, but varied widely over the 18-year span. Output increased 3.1 percent annually and hours, 2.1 percent.[2] (See table 1.) During the same period in the private economy, productivity advances averaged 2.8 percent a year.

Factors that have contributed to the advance of productivity in the food service industry are the spread of modern management techniques and work organization, particularly in the rapidly expanding fast food segment of the industry. Menus have been simplified and standardized, and menu items are increasingly prepared off premise, reducing on-premise employee-hour requirements. Layouts of establishments are designed to minimize walking time of personnel. Technological innovations, such as the microwave oven, reduce cooking time. Finally, the decline in the number of single-unit drinking establishments (usually proprietorships and partnerships) has resulted in the disappearance of marginal enterprises.

Trends, 1958–76

Between 1958 and 1964, output per hour rose at an average annual rate of only 0.5 percent, reflecting gains below the long-term trend in both output and aggregate hours. Between 1964 and 1968, productivity increases accelerated, averaging 2.3 percent a year, as output grew rapidly and hours advanced moderately. From 1968 forward, productivity improvement again slackened to 0.4 percent a year; however, output continued to expand vigorously, accompanied by relatively large increases in hours.

Year-to-year changes in the trend of labor productivity deviated significantly from the long-term average. The largest annual gain, 3.4 percent, occurred in 1970; the largest decline, 2.2 percent, occurred the following year, when output rose slightly and hours expanded sharply.

Output and growth factors. The industry's output gains reflect an upward trend in real per capita spending on meals eaten away from home. At $159 per capita in 1976 (constant 1972 dollars), such spending has risen 24 percent since the mid-1960's with all of the rise having occurred since 1973.[3] The relation between changes in industry output and changes in real per capita income is illustrated below:

	Output	*Real per capita income*
1958–76	3.1	2.8
1958–63	1.6	1.5
1963–68	4.0	4.0
1968–76	3.0	2.3

Relatively slow advances in real per capita income were associated with modest output growth in the earlier years; while rapid income increases were linked with accelerated output rates in the later years.

The long-term trend in food service output was also influenced by the more rapid rise in the number

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of households headed by unattached individuals (97 percent between 1960 and 1975) than in the number of families (24 percent). Such individuals are more likely to eat out than families: according to the latest Bureau of Labor Statistics consumer expenditure survey, 1-person households, on average, spend 40 percent of their food budgets on meals away from home, compared with 25 percent for families (the proportion diminishes as size of family increases).[4] Moreover, between 1960 and 1975, real incomes rose faster for unattached individuals than for families—56 and 34 percent, in constant dollars.[5]

Another important factor that bolstered output gains in food service was the increase in the number and proportion of wives in outside employment, contributing to family incomes. In 1975, 44 percent of all wives (husband present) held a paid job, compared with 31 percent in 1960. Real income of such families climbed 37 percent over that period; real incomes increased 27 percent for families with wives not in paid employment. The absolute difference in income between the two categories, 35 percent in 1975, made a significantly larger absolute difference in their spending on meals eaten out—51 percent.[6]

The overall increase in spending for meals and snacks eaten away from home was accompanied by a shift from full-service restaurants to fast-food establishments. This shift has given rise to greater frequency of eating out and to consumption of lower priced meals. The share in total industry receipts of restaurants and lunchrooms declined from 62 percent in 1958 to 50 percent in 1972; over the same period, the share of refreshment places (which includes most fast-food units) quadrupled, and stood at 26 percent in 1972. Commercial cafeterias raised their share from 6 to 8 percent. The remaining share of industry receipts is accounted for mostly by drinking establishments which, like restaurants, suffered a large loss in market penetration over the 1958–76 period.

The average transaction in fast-food establishments is about three-quarters of that in full-service restaurants.[7] This does not mean that consumer preferences have shifted to cheaper foods; surveys of representative menus conducted by *Institutions/Volume Feeding* do not indicate significant changes in the choice of the major classes of breakfast foods, dinner entrees, or desserts.[8] Rather, the evident increase in the number of transactions at fast-food establishments has been accompanied by fewer services rendered to consumers (when compared with full-service restaurants) and by a decline in the variety of foods offered, reflecting standardized menus.[9]

Employment doubles and hours moderate. Employment in eating and drinking places (currently 3.7 million) doubled between 1958 and 1976, rising at an average annual rate of 3.9 percent. Its growth, like that of output, was comparatively slow between 1958 and 1963 (1.7 percent annually), but accelerated from 1964 forward at an annual rate of 4.6 percent.

Total hours of persons engaged in the industry rose about half as much as employment, with average weekly hours for nonsupervisory workers declining from 35.6 in 1958 to 28.0 in 1976. This drop in weekly hours resulted in part from the expansion of part-time work. In 1975, 51 percent of all workers in the industry worked part time, compared with 32 percent in 1962.[10] Moreover, the number of proprietors and partners dropped, and the working hours of supervisory personnel declined from an estimated 61 hours in 1958 to 51 hours in 1975.

The occupational composition of food service workers has not changed significantly since detailed data first became available in 1972. (See table 2.) More than half of the employees occupy positions such as waiters, waiter assistants, counter and fountain workers, or dishwashers. About one-third were cooks and bartenders and the remainder performed clerical, or managerial and administrative tasks.[11] Limited data for earlier years indicate a steady contraction in the number of waiters and waitresses, and an expansion in jobs associated with counter work. In general, trends in food and equipment technology, together with organization changes, have increasingly favored the employment of low-skilled persons in the industry—developments also promoted by rising labor costs,[12] and the difficulty of attracting a stable work force.

Data on the work experience, age, and sex of food service workers indicate a generally high turnover rate. The proportion in full-time, year-round jobs, 22

Table 1. Indexes of productivity, output, and hours in food service establishments, 1958–76

[1967 = 100]

Year	Output per hour of all persons	Output	Hours of all persons
1958	91.3	78.8	86.3
1959	90.3	81.0	89.7
1960	90.0	81.6	90.7
1961	90.8	81.5	89.8
1962	91.8	84.0	91.5
1963	93.8	86.0	91.7
1964	93.1	89.8	96.5
1965	96.0	95.5	99.5
1966	98.0	99.4	101.4
1967	100.0	100.0	100.0
1968	101.9	105.6	103.6
1969	100.1	106.3	106.2
1970	103.5	110.4	106.7
1971	101.2	111.6	110.3
1972	104.4	118.5	113.5
1973	106.0	124.6	117.5
1974	102.8	122.9	119.6
1975	105.0	127.4	121.3
1976	103.2	131.9	127.8

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Table 2. Employment in food service occupations, 1972 and 1976

Occupation	1972		1976	
	Number	Percent	Number	Percent
Restaurant, cafeteria, and bar managers	494	13.2	505	12.1
Food service workers	3,263	87.0	3,919	88.6
Bartenders	201	5.4	261	5.9
Waiters and assistants	1,263	33.6	1,450	32.8
Cooks	866	23.1	1,065	24.1
Dishwashers	218	5.8	251	5.7
Counter and fountain workers	307	8.2	421	9.5
Other (except managerial)	408	10.9	471	10.6

SOURCE: BLS **Employment and Earnings.** Comparable data for years prior to 1972 are not available.

percent in 1976, was the lowest for any occupational category reported by the Bureau of Labor Statistics (except for private household workers). It compared with 53 percent for all service-producing workers outside of households, and 54 percent for all occupational groups. Women accounted for 64 percent of all workers in the industry, compared with 51 percent for all services outside households, and 44 percent for all occupational groups. Women are generally more likely than men to hold part-time jobs in the industry.

Furthermore, the average age of the work force has declined over the past 15 years, suggesting a decline in the proportion of seasoned, experienced workers. In 1975, teenagers accounted for 30 percent of all food service workers, compared with 17 percent for all service industries, and 8 percent for total nonagricultural payroll employment. Between 1960 and 1970, the median age of food service workers declined from 42 to 33 years. For the labor force as a whole, it remained constant at 40 years.

Growth in multi-unit firms

The eating and drinking place industry changed considerably during the 1958–76 period. The number of establishments dropped 4 percent, to 359,500, between 1958 and 1972 (the most recent year for which data are available). All of the decline occurred in drinking establishments serving alcoholic beverages. While the number of drinking places dropped 7 percent, eating places rose 10 percent with nearly all of the rise in multi-unit operations, usually run by one firm. Multi-unit establishments almost doubled over the 14-year period; single-unit establishments grew by less than 2 percent; and owner-operator units without paid employees dropped by one-third. No comparable changes occurred for drinking places, virtually all of which were owner-operated in both 1958 and 1972.

The impact of these changes on the industry's labor productivity cannot be demonstrated. Eating place sales per employee rose during the period, but variations from the average by employment size class of single- or multi-unit establishments are influenced by the menu offered, and therefore cannot be used to indicate changes in labor productivity of specific employment size classes. However, efficiencies in the use of capital, materials, and organizational inputs undoubtedly have been greater in multi-unit than in single-unit establishments, and this largely accounts for the more rapid expansion of multi-unit businesses.

The changes in the structure of the food service industry were marked by the expansion of fast-food establishments. According to a Department of Commerce survey, there were 43,000 franchised eating establishments in 1975, representing an estimated 20 percent of all eating and drinking places, and accounting for 25 percent of industry sales.[13] A study by the U.S. Senate Select Committee on Small Business shows that the number of fast food units nearly tripled between 1960 and 1971, while the number of restaurants, other than fast food, declined 9 percent to 210,000.[14] The expansion of fast-food establishments has introduced profound systemic changes in the food industry which lie at the root of recent and future productivity improvements.

Fast-food operators introduced principles of industrial engineering in retail food services—including work organization and layout—which had previously been applied mainly by large institutional and industrial caterers or food contractors.[15] These principles have been implemented throughout numerous franchised or company-owned outlets. According to a survey by The Conference Board,[16] all or the great majority of fast-food franchisers participating in the survey distributed operating manuals; operated management training programs; trained franchisee employees; selected sites; and designed facilities and layout. Moreover, many services to franchisees were rendered on a continuing basis, including counseling through field personnel; training of new employees; help with maintaining quality standards; and centralized purchasing. These organizational features are more prevalent among company-owned fast-food chains than among franchised establishments, and represent key elements in standardizing managerial practices.[17]

Labor-saving innovations

Productivity gains in the food service industry have been associated with three kinds of technological advances: (1) the off-premise preparation of foods which permits reduction in on-premise preparation time and employee-hours, (2) the simplification of work processess through improvements in materials handling and cooking devices, and (3) innovations in food preservation methods and equipment. Food service establishments have not adopted these technologies to the same extent; many of the higher priced

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restaurants, for example, capitalize on the culinary skills of their staff, and use off-premise prepared (or convenience) foods on only a limited scale.[18] The numerous single-unit small diners and refreshment places that characterize much of the industry are often slow to modernize their equipment, or unable to do so altogether. The trend, however, is in the direction of shortened food preparation time and higher ratios of equipment to employment.

Food preparation. According to a 1974 survey, 70 percent of all respondents used fresh frozen meats and 56 percent used meats prepared to some extent off premises (for example, pre-cut to meet portion standards). Seafood, fresh frozen or otherwise partially prepared, was served by more than 60 percent of all respondents, and fruits and vegetables prepared fully or partially off premises were offered by 40 percent. A significant proportion of respondents also served baked goods prepared off premise. The great majority using frozen or other partially prepared foods served them regularly, and not merely as supplements to conventionally prepared foods.[19] However, much of the food served is still prepared on the premises. For example, roughly 40 percent of all standard meat dishes—that is, fried chicken, meat balls, roast beef, steaks—are still prepared by restaurant staff.

Food service establishments have been substituting off-premise for on-premise prepared foods in order to reduce labor costs and to control the portions served. Almost three-fifths of the respondents in a 1972 survey gave these two reasons for serving convenience foods.[20] Other respondents cited the broadened menu, as well as reduction in costs per portion made possible by convenience foods. (Although a substantial proportion of off-premise prepared food originates in central kitchens or commissaries classified in the industry, some originates in food processing industries. See the appendix for a discussion of the effects on the productivity measure.)

The use of foods prepared off premise facilitates large-scale operations. Units with 25 employees or more are more likely to offer such foods than smaller firms. Frozen entrees, for example, were served by more than two-fifths of the larger establishments, compared with one-third or fewer of the smaller ones. Frozen baked goods and vegetables showed the same pattern.[21] Also, the use of such foods has improved the uniformity of food quality, saved on investment in inventory, and has enabled the industry to reduce the level of needed culinary skills—partly in response to the shortage of qualified cooks and chefs.

Food processing. The trend in the industry's capital expenditures suggests that diffusion of innovated food service equipment has been rapid for corporate establishments but slow for others. Overall, capital expenditures rose 31 percent between 1968 and 1972, but much less in constant dollars—the same rate of advance as for the plant and equipment outlays of U.S. business as a whole. Corporate food service businesses, however, raised capital expenditures by 67 percent over the period; proprietary firms and partnerships, partly because of the decline in their number, lowered capital spending by 15 percent. Hours of all persons in the industry rose 7 percent between 1968 and 1972.[22]

The major improvement in food service equipment has been the microwave oven. The heat generated in microwave ovens is distributed uniformly throughout the product being cooked (rather than conducted from its surface inward, as in conventional ovens). Moreover, all the energy produced is absorbed by the product, rather than by the oven walls and the surrounding air.[23] Hence, processing time is greatly reduced, although microwave ovens are often supplemented by auxiliary equipment so that an acceptable product texture and surface color is obtained.

Forced convection ovens have been rapidly adopted in the industry. These ovens are reported to reduce cooking time up to 50 percent by using a recirculating loop with a built-in fan to reheat the air within the cooking chamber, thereby increasing the rate of heat transfer to the product. Forced convection ovens are being installed in most new operations, and are replacing free-convection ovens in many existing facilities.[24]

Fat fryers have been refined for more convenient operation and better product quality. Processing control has been improved by more accurate timers and thermostats, and by automatic basket lifts which terminate cooking after a preassigned period. Pressure containers, which increase the heat to the product and thus speed up processing time, have been introduced.[25]

Gas burning broilers are still widely used, but commercial installations are beginning to use infrared heat to generate high temperatures and shorten cooking time. Operations producing large volumes of processed foods are increasingly using continuous-flow broilers which require only unskilled labor once the temperature and speed of the transfer belt have been set.[26]

Food preservation. Important developments have occurred in the quick freezing of fresh foods and in the efficient thawing of frozen foods. Minor but significant changes have also been taking place in other phases of food preservation. Whether or not food service establishments operate their own food proc-

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essing and preservation equipment, these changes tend to reduce on-premise preparation time, improve the quality, and expand the variety of foods served.

The development of thawing equipment has been spurred by concern with the nutritional and chemical deterioration of foods allowed to unfreeze for long periods and by the larger size of frozen food packages used in the industry. Microwave thawing systems can temper frozen foods in a few minutes.[27] Thus, reduction in on-premise preparation time is sustained when efficient thawing systems are used.

Changes in food preservation methods, other than freezing, have been modest in their impact on the food service industry. Dehydration, the most widely used preservation method, underwent no significant evolution during the period (except for freeze-drying of coffee).[28] In canning, however, the aseptic process was introduced and spread rapidly. The process, which involves packing sterilized food in sterilized containers in a sterile environment, eliminates the change in flavor, texture, and appearance that usually results from thermal treatment of products for canning.[29] While the use of all canned foods cuts the time spent in on-premise preparation (in comparison with cooking from the raw), the introduction of aseptically canned foods enhances the acceptability and extends the variety of foods.

Some improvements ahead

Productivity in the food service industry should continue to improve. The adoption of labor-saving equipment and off-premise prepared foods is likely to be spurred by the expansion of corporate establishments with their focus on efficient management. The continued decline in the number of smaller marginal firms, while perhaps a loss in terms of customer convenience, will nonetheless help raise industry productivity.

Developments in food processing and preservation technology will probably make for more widespread off-premise preparation of food, especially insofar as such developments improve quality and help broaden menu choices. Irradiation or radiation-pasteurization may become acceptable in preserving foods high in moisture content and therefore liable to rapid bacterial decomposition (for example, fish, fruits, and vegetables); freeze-drying may spread to products such as eggs; and aseptic canning is likely to spread.

Completely integrated food service systems, with precisely timed and mechanized transfer operations, may increasingly mark the spread of contract feeding (they are not likely to prove feasible in smaller retail operations). In such systems, also called a "cooking street," two persons operate five pieces of equipment —a steam cooker, a water cooker, a deep fat fryer, a grill, and a broiler. All pieces are removable without tools, and there is a minimum of complex mechanisms. These "cooking streets" result in a very high ratio of meals served per employee;[30] however, menus are necessarily restricted and there is little if any floor service.

Standard menus and simple equipment have, in part, been dictated by persistent shortages of skilled kitchen personnel, and the resulting need for equipment that can be operated with minimum training by unskilled persons of whom a high turnover rate is expected. In addition, customer self-service has spread, to some extent, to full-service restaurants with buffet offering. In fast food shops, customers often accept the job of clearing their tables. Such self-service tends to reduce the industry's reliance on low-skilled labor.

Over the long term, the supply of low-skilled workers is expected to contract, assuming full or near full employment is attained. Based on that assumption, recent projections indicate a relatively small rise in the number of low-skilled or unskilled workers to the end of the decade; and a decline in the first half of the 1980's.[31] Incipient labor shortages would compel the industry to upgrade its work force and to develop career progression systems.[32] At the same time, the industry will very likely continue to substitute capital for labor, possibly at a stepped-up rate.

Output growth in the food service industry hinges, of course, on continued gains in real family and per capita income. The expansion in the proportion of working wives should continue to raise the demand for food eaten away from home.

Some productivity advances may arise from certain changes in patterns of eating out. The traditional concept of three meals a day—tending to bunch labor inputs at peak periods—has in part given way to and in part been supplemented by a greater frequency of consuming snacks or "mini-meals." To the extent this pattern prevails, more efficient utilization of labor and capital would be attained, but food outlets would have to operate longer hours and therefore would have to generate higher output volume to ensure productivity gains.

[1] Eating and drinking establishments include restaurants, lunch counters, refreshments stands, cafeterias, and other facilities selling food or drink (including alcoholic beverages) for on-premise consumption. Eating facilities in department stores, hotels, and motels are excluded, unless

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leased to outside operators. The industry is classified as Eating and Drinking Places (code 58) in the Office of Management and Budget's *1972 Standard Industrial Classification Manual.*

[2] The average annual rates of change are based on the linear least squares trend of the logarithms of the index number. Extension of the indexes will appear in the annual BLS bulletin, *Productivity Indexes for Selected Industries.*

[3] Corinne LeBovit, "The Changing Pattern of Eating Out," *National Food Situation,* No. 144, May 1973, p. 31. Data for recent years were derived from data compiled by the U.S. Department of Commerce.

[4] *Consumer Expenditure Survey Series: Diary Data 1972,* Report 448–1 (Bureau of Labor Statistics, 1975).

[5] Most of the 15-year real income gain of primary individuals occurred from 1965 forward—33 percent, compared with 16 percent for real family incomes. Gains in the average income of primary individuals are in part attributable to the rise in the average social security benefit which, for widows and widowers, more than tripled between 1960 and 1975. The total number eligible more than doubled. All but $6 of the $124 monthly increase in the average benefit occurred from 1965 forward.

[6] *Selected Family Characteristics and Average Weekly Expenditures by Income Classes of Family Income Before Taxes,* Consumer Expenditure Diary Survey (Bureau of Labor Statistics, 1976).

[7] Corinne LeBovit, "The Changing Pattern," p. 30.

[8] See *Institutions/Volume Feeding* (Chicago, Cahners Publishing Co.), April 1975.

[9] See Theodore Levitt, "Production Line Approach to Service," *Harvard Business Review,* September-October 1972, beginning on page 41. Also Thomas F. Powers, "Food Service in 1985," *The Cornell H. R. A. Quarterly,* May 1976, p. 47.

[10] Unpublished data on work experience of the population in 1962 and 1975, Bureau of Labor Statistics.

[11] "The food services have been drastically reducing the number of skilled workers by simplifying the operation so that it can be run by quickly trained, low-paid, high-turnover employees." See Daniel M. Seifer, "The Service Industries: Automation, Minimum Wages, Unemployment," *Bulletin of Business Research,* The Ohio State University, Vol. 46, No. 8; G. E. Livingston, "Changes in the Food Service Industry," *The Cornell H. R. A. Quarterly,* May 1974, p. 15; and "Young Women Who Work, An Interview With Myra Wolfgang," Irving Howe, ed., *The World of The Blue-Collar Worker* (New York, Dissent Publishing Co., 1972), p. 26.

[12] See Thomas F. Powers. "Labor Supply, Payroll Costs and Changes." *The Cornell H. R. A. Quarterly,* May 1974, beginning on page 5.

[13] Andrew Kostecka. *Franchising in the Economy,* 1974–76 (Washington, D.C., U.S. Department of Commerce, 1976), p. 7. See also Philip B. Dwoskin, "Fast Food Franchises: Market potentials for agriculture products in foreign and domestic markets," *Marketing and Transportation Situation,* No. 196, February 1975, beginning on page 20.

[14] Quoted in Thomas F. Powers, ed., *The Future of Food Service: A Basis for Planning* (University Park, Pa., The Pennsylvania State University, Food Service and Housing Administration, 1974), pp. 35 and 41.

[15] For some applications of industrial engineering to food services, see Raymond Pedderson et al, *Increasing Productivity in Food Service* (Chicago, Institutions/Volume Feeding Management, 1973), 206 pp. Economies through centralized purchasing appear in large measure to have been achieved through distributors in the wholesale industries. See Charles Sirey, Jr. "Food Service Logistics: Roadsigns in the Wilderness," *Institutions/Volume Feeding,* December 1970, beginning on page 53.

[16] E. Patrick McGuire, *Franchised Distribution* (New York, The Conference Board, 1971).

[17] The McDonald's operations manual is a 385-page book detailed down to the most minute facets of running the stand and its machinery. See Charles G. Burck, "Franchising's Troubled Dream World," *Fortune,* March 1970, p. 116.

[18] Marshall C. Warfel, "Convenience Foods—What is the Score?" *The Cornell H.R.A. Quarterly,* May 1971, beginning on page 33.

[19] See *Institutions/Volume Feeding,* December 1974.

[20] Ibid., September 1972.

[21] Ibid., December 1974.

[22] The long-term growth rate of capital in the food service industry (eating and drinking places) has been estimated at 3.4 percent annually for 1929–63, nearly twice that for total retail trade. The growth of capital per employee-hour has been estimated at 0.6 percent annually for the same period, which compares with 0.7 percent for total retailing. See David Schwartzman, *The Decline of Service in Retail Trade* (Pullman, Washington, State University, 1971), p. 67.

[23] The conversion of electrical into radiation energy remains relatively inefficient, although one manufacturer reportedly has claimed that his brand of microwave oven converts 72 percent of electrical into radiation energy. The average conversion range is estimated at 30 to 50 percent for all brands. See Frank W. Schmidt and Stephen Bartlett, "Food Processing and Preparation Equipment as It Shapes the Future of Food Service," in Thomas F. Powers, ed. *The Future of Food Service,* p. 94.

[24] Ibid., p. 93.

[25] Ibid., p. 100.

[26] Ibid., p. 104.

[27] Ibid., pp. 89–90.

[28] Ibid., p. 149.

[29] Ibid., p. 191.

[30] See the section on completely integrated systems in "Food Processing and Preparation Equipment," *The Future of Food Service,* beginning on page 109. Also see "Health Services," *Technological Change and Manpower Trends in Six Industries,* Bulletin 1817 (Bureau of Labor Statistics 1974) p. 58.

[31] See Harold Wool, "Future labor supply for lower level occupations," *Monthly Labor Review,* March 1976, pp. 27–28.

[32] The Employment and Training Administration of the U.S. Department of Labor has sponsored several studies on employment and career progression in the food service industry. For example, see Gary L. Hotchkin, *Development of Career Progression Systems for Employees in the Food Service Industry* (Chicago, National Restaurant Association, 1975).

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Productivity growth average in farm machinery manufacturing

Productivity gains, aided by new technology, especially computers, but moderated by cyclical downturns, averaged 2.6 percent a year over the 1958–80 period

ARTHUR S. HERMAN AND JOHN W. FERRIS

Productivity, as measured by output per employee hour, in farm machinery manufacturing[1] was about the same as the average for all manufacturing industries over the 1958–80 period. Growth was aided by numerically controlled machine tools, automatic welding, computerized manufacturing, industrial robots, and computerized automatic warehouses, but was partially offset by sharp declines in demand. Almost every decline in productivity during the period studied can be associated with a drop in output, which, in turn, usually coincides with downturns in the economy. During the 22-year period, productivity in the farm machinery industry grew at a rate of 2.6 percent a year, compared with 2.7 percent per year for all manufacturing industries; 1.9 percent for construction machinery, an industry which uses similar manufacturing techniques; and 3.2 percent for motor vehicles, another similar industry.

Output, productivity follow farm income

Productivity growth in the farm machinery industry can be divided into three distinct periods. From 1958–65, productivity grew at an annual rate of 1.7 percent; from 1965–74, it accelerated to a 3.3-percent rate; and from 1974–80, slowed to 0.2 percent. (See table 1.) The higher rate of gain during the 1965–74 period can be associated with years of very high output, fueled by dramatic increases in farm income.

Productivity changes in the farm machinery industry are closely tied to output changes over the short term. Demand for farm machinery is based on a number of interrelated factors. A major factor is the overall state of the economy. However, an even more directly related factor is farm income. Changes in the output of farm machinery closely parallel changes in farm income. When farm income is up, farmers tend to purchase new equipment. Among the determinants of income are crop size, both actual and anticipated in the near future, and farm prices. Crop size is, of course, affected by a number of variables, including the weather, farm prices, government policies, and the worldwide food supply. Other important factors affecting the production of farm machinery are farmers' costs, such as for loans, new machinery, land, fertilizers, and pesticides, as well as age and condition of existing equipment and imports and exports of farm equipment.

When income is low and prospects appear poor, farmers tend to make do by repairing, rather than replacing, existing equipment. Conversely, when income is growing and prospects for further expansion of profits appear good, they tend to purchase new, more productive equipment. Demand for machinery increases significantly during these expansive periods, as does productivity.

The impact of the numerous variables affecting demand changes rapidly over time; therefore, output of farm machinery shows wide swings. Productivity, however, moves in a less volatile manner. For example, output grew by 6.3 percent between 1958 and 1959, but

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then dropped precipitously in 1960, a recession year, falling 18.3 percent. Concomitantly, productivity had no growth in 1959 and dropped sharply, by 7.1 percent, in 1960. In 1966, output increased substantially, up 19.4 percent, then declined for 4 consecutive years, one of which was the recession year of 1970. Following output, productivity also grew substantially in 1966, up 6.2 percent, and then dropped sharply, averaging 0.8 percent from 1967 to 1970.

The early 1970's were a period of high output growth, with gains of 16.5 percent in 1972, 21.3 percent in 1973, and 14.3 percent in 1974. This strong growth can be attributed to a sharp increase in farm income resulting, in part, from large exports of farm products, including sales of grain to Russia. Productivity recorded its largest advances during this period, with increases of 8.9 percent in 1971, 9.3 percent in 1972, 5.2 percent in 1973, and 3.6 percent in 1974.

In the more recent period—1980, a recession year—output dropped 15.1 percent, as farm income declined precipitously. In turn, productivity declined 6.7 percent.

A factor affecting output over the long term is the continuously increasing size of farms. The average farm in the United States has shown a significant increase in size, growing about 40 percent in acreage over the period studied.[2] This created a need for an increase in the physical dimensions and horsepower of farm machinery. To cope with the growing acreage, farmers purchased larger, more powerful equipment, rather than increasing their labor force. For example, the average horsepower (PTO) rating of tractors was 106 in 1980, compared with 67 in 1958. Demand for farm equipment has also been enhanced by such equipment as 4-wheel drive tractors, which allow farming in previously marginal areas, and such amenities as air conditioning and stereo radio and cassette equipment in the cabs of the larger units.

Demand for larger, more productive farm machinery has been one factor leading to the industry's long-term growth rate in output of 4.2 percent, somewhat higher than the 3.8 percent for the total manufacturing sector. Highly advanced farm equipment is one of many reasons that productivity has been significantly higher in the farm sector than in the nonfarm sector.

Plants located in Farm Belt

The farm machinery manufacturing industry has paralleled the growth of agriculture in the United States. Some of the larger firms can trace their origins to the development of horse drawn harvesting equipment in the early 1800's. Therefore, farm machinery manufacturing is a mature industry, producing a variety of equipment for both U.S. markets and export.

There were 2,148 establishments in the farm machinery industry as of 1977, a significant increase over the 1,949 establishments reported in 1958. The number of employees per establishment has remained fairly constant, dropping slightly from 74 in 1958 to 70 in 1977 (the average for all manufacturing industries was 53).

Table 1. Output per employee hour and related indexes in the farm machinery equipment industry, 1958–80

[1977=100]

Year	Output per hour			Output	Employee hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1958	65.1	64.9	65.5	49.4	75.9	76.1	75.4
1959	65.1	63.4	70.3	52.5	80.7	82.8	74.7
1960	60.5	61.3	58.6	42.9	70.9	70.0	73.2
1961	62.9	61.3	67.7	45.7	72.7	74.5	67.5
1962	65.1	65.1	64.8	48.8	75.0	75.0	75.3
1963	66.6	64.3	74.3	53.7	80.6	83.5	72.3
1964	70.2	66.9	82.0	60.1	85.6	89.9	73.3
1965	72.2	68.6	84.8	64.0	88.6	93.3	75.5
1966	76.7	72.3	92.7	76.4	99.6	105.6	82.4
1967	76.8	73.3	88.8	73.6	95.8	100.4	82.9
1968	76.7	75.0	82.1	70.8	92.3	94.4	86.2
1969	73.8	73.2	75.9	65.8	89.1	89.9	86.7
1970	75.7	75.2	77.3	65.1	86.0	86.6	84.2
1971	82.4	83.0	81.0	66.2	80.3	79.8	81.7
1972	90.1	87.0	99.9	77.1	85.6	88.6	77.2
1973	94.8	90.7	109.2	93.5	98.6	103.1	85.6
1974	98.2	92.6	118.3	106.9	108.9	115.4	90.4
1975	97.7	95.3	105.2	100.0	102.4	104.9	95.1
1976	101.1	100.5	103.1	98.9	97.8	98.4	95.9
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	100.8	100.1	103.1	95.6	94.8	95.5	92.7
1979	103.2	101.7	108.0	114.7	111.1	112.8	106.2
1980	96.3	99.6	88.1	97.4	101.1	97.8	110.6
	Average annual rates of change (percent)[1]						
1958–80	2.6	2.7	2.4	4.2	1.5	1.5	1.8
1958–65	1.7	1.0	3.9	3.9	2.2	2.9	([2])
1965–74	3.3	3.4	2.9	3.7	0.5	0.4	0.8
1974–80	0.2	1.2	−2.9	−0.1	−0.3	−1.4	2.9

[1] Based on the least squares trend of the logarithms of the index numbers.
[2] Rate of change is less than 0.05 percent.

The industry has a few very large firms with numerous establishments making a variety of equipment—tractors, combines, and other harvesting equipment, crop sprayers, plows, harrows, planters, cultivators, hay balers, and fertilizing equipment. These firms are highly integrated and manufacture many of the parts that are assembled into the final products, including both gasoline and diesel engines, as well as replacement parts for the older units in operation. The large firms generally produce the larger equipment, such as grain harvesting combines, 4-wheel drive tractors, and accessories. There are numerous medium and small firms in the industry. They usually specialize in a particular line or type of equipment, such as milking, poultry, or irrigation equipment. Many of them serve local markets for highly specialized equipment. The smaller firms also make lawn and garden equipment, such as walk-behind lawnmowers and snowblowers.

Farm machinery manufacturers are concentrated in the Farm Belt, with most plants in midwestern States—Illinois, Wisconsin, Minnesota, Iowa, Nebraska, and

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Kansas. Texas and California also have a large number of plants.

The largest export market for U.S. manufacturers is Canada. In turn, Canada provides the largest amount of imports of farm machinery into the United States.

Employment and hours rapidly adjusted

Over the 1958–80 period, the number and hours of production workers and nonproduction workers in the farm machinery industry have grown at similar rates. Production workers increased at an average annual rate of 1.7 percent and their hours grew 1.5 percent. Nonproduction workers grew at rate of 1.7 percent, and their hours increased at a rate of 1.8 percent.

Year-to-year changes in employment and hours in this industry tend to move in a similar but less volatile pattern than changes in output. This indicates that the industry can adjust its hours and employment fairly rapidly to changing demand. For example, when demand is falling overtime usually is cut, the number of shifts worked are reduced, the normal summer shutdowns may be extended, and workers may be laid off.

The extent of the adjustments in hours due to changes in demand is influenced by the occupational makeup of the work force. In the farm machinery industry, the largest occupational group is operatives, most of whom are assemblers. Welders, precision machine operators, punch and stamp machine operators, and transportation operators also are important. These employees, along with laborers (mainly freight handlers) are most affected by reductions in demand. The industry also employs a large group of craftworkers—machinists, mechanics, tool and die makers, and blue-collar supervisors.[3] Craftworkers are least affected by declines in production; because of their skill levels, employers are reluctant to lay them off for fear that they may not be available when demand picks up.

Technology aids productivity

Technological change varies greatly among plants in the farm machinery industry. The more advanced highly sophisticated equipment is used, for the most part, by larger firms engaged in mass production of various products. Slower changes are undertaken by the smaller firms which make short runs of highly specialized products and generally have limited capital.[4]

The level of complexity of farm machinery manufacturing differs greatly depending on the product, which can range from a simple plow pulled by a tractor to a complex self-propelled grain harvesting combine. However, there are factors common to most farm equipment manufacturing: most of the components are made of iron and steel; they are shaped by such processes as casting, cutting, stamping, punching, boring, and machining; and they are joined to form the final product in an assembly operation which uses welding and fastening with air powered tools. Farm machinery is usually finished by painting, either in the parts stage or as a completed unit.

Because of the complex nature of many of the products, the varied manufacturing operations involved in producing units, and the fact that farm machinery manufacturing is a mature industry with many old plants, there are numerous areas that are subject to technological change. The larger companies usually make most of the parts they assemble into the final product. Therefore, the technological innovations they employ cover a range of manufacturing operations and have resulted in significant labor savings.

During the 1960's, capital expenditures per employee for new plant and equipment were consistently below the average for all manufacturing industries. However, because of sustained demand for farm equipment in the early 1970's which strained the industry's capacity,[5] firms began to increase their capital expenditures for new plant and equipment. By 1975, capital expenditures per employee had almost tripled, compared to the level in 1970. This resulted in the installation of advanced manufacturing equipment and large scale plant modernization and probably was one of the factors leading to a higher rate of productivity increase during the 1970's than during the earlier decade.

Computers are among the widespread innovations with significant impact upon the industry. They are used for many functions, including inventory control, data collection, tracking progress of semi-completed products, design, and for numerous accounting and other business purposes. In recent years, computers have been more directly used for manufacturing operations on the factory floor.

Numerically controlled machine tools are used extensively by major companies in the manufacture of the parts used in assembling farm machinery. A recent innovation is computerized numerically controlled machine tools, which are more versatile than standard equipment because they can be programmed for changes by the operator rather than from tapes. One unit installed in a large firm is a completely computer-controlled gear case transfer line, using numerically controlled machine tools, where parts automatically go through 87 machining operations.[6]

One plant is experimenting with a change in machine tool layout, from the traditional setup consisting of banks of individual machines designed for a single operation to cells of machine tools based on workflow. This new layout requires high volume, but has cut bottlenecks in production and has resulted in operating efficiencies.

Automatic welding has replaced manual welding in a number of installations. In addition, industrial robots

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are being introduced for welding functions, resulting in more versatile automatic welding operations.

Significant efforts have been made to increase efficiency in materials handling and warehousing functions. These functions are very important because of the numerous parts that must be moved, the many operations that must be carried out, and the large size of the factories involved in the manufacture of the more complex farm machines. A number of plants have installed computerized automatic warehousing and materials handling systems. In one plant, such a system is used for the materials receiving warehouse. The system is located in a special high rise building attached to the single story plant. Materials are shipped in using the plant's containers, logged on the computer, and moved automatically to a preassigned location. When needed, they are called for by the computer, which automatically sends a remote controlled sideloader for them, and are sent via conveyor to the location requesting them. This warehouse is run by a single computer operator. The installation of this system resulted in substantial labor savings, while doubling warehouse capacity, because the previously used equipment required numerous forklift operators.

Sideloaders are an important innovation in the industry, even though they require operators. They are narrower and higher than the conventional forklifts which they replace, allowing for increased storage space and versatility in the warehouse. Sideloaders are increasingly being used in semi-automatic computerized high rise warehousing systems installed in a number of plants.

An example of the most advanced technology for assembly line manufacture in the industry is a recently built tractor plant designed specifically for computer control.[7] This plant is unique in that almost all phases of its operations are computer controlled or directed. The plant has high rise computerized automatic warehouses. The parts to be assembled are programmed to move in the correct sequence to produce a finished tractor via conveyor through the various assembly lines. This is a major advance over the system where parts are made in advance and stored until needed, boxes of parts are moved to the assembly line via forklift trucks, and assemblers pick the correct parts out of the boxes to assemble the final product. The new plant uses industrial robots for welding and painting. The robotic painting machines are programmed to move their spray guns to paint the correct part of the tractor chassis as it moves by on the conveyor line. This differs from conventional automatic spray painting equipment, which uses fixed spray guns, in that it more closely approximates a human spray painter. Almost all welds for the frame of the tractor cabs made at this plant are done on an electronically controlled automatic framing buck which is run by a single operator. The assembly lines are set up so that fasteners and other small parts are fed directly to the assemblers at the correct height for their use. This plant's design significantly cuts parts inventory, reduces handling, increases manufacturing efficiency, and results in overall labor savings.

Besides robotic painting, which is just being introduced in the industry, there are a number of other innovations that increase painting efficiency. One system, electrostatic painting, has been used for a number of years. In this process, electrically charged parts move through an automatic paint spray booth, with the paint mist attracted to the charged part. Another innovation is electric dip paint lines, in which charged parts are dipped into a paint-filled tank from which paint is precipitated out on the part. These systems have resulted in savings in both paint and labor.

While the advanced innovations are most readily adapted by the larger multiline companies, smaller firms in the industry tend to introduce new technology more slowly. Many of the latter specialize in a particular product, such as pipeline milking units or self-propelled irrigation systems. Although these units are usually produced from common components (pipes, tanks, spray guns, and pumps), they are generally assembled to fit a particular farmer's need. Because of the semicustom nature of production used by these smaller firms, it is difficult to adapt much of the available new technology which is designed for volume production. In addition, many of the smaller firms are located in rural areas near the farms they serve and do not have the access to the capital markets as do the major companies.

Future trends uncertain

Changes in output and productivity in the farm machinery industry are expected to continue to reflect changes in farm income. In the near future, the outlook for farm income is uncertain. It has been falling since 1979; and currently, there are pressures on farm prices that are expected to slash farm profits. In addition, such factors as high interest rates and high fertilizer and pesticide costs are also expected to reduce farm income. The export market is uncertain, and farm prices are down. This situation could result in a continuation of the recent negative pressure on demand for farm machinery. In addition, technological changes in the near future may be affected by the financial difficulties of a number of the major companies in the industry, which are expected to limit capital expenditures for new plant and equipment.

Over the long term, modernization of plant and equipment is expected to continue in the farm machinery industry, with particular emphasis on labor savings and cost reduction. These changes will be fueled by possible competition with Japan in the market for larger

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farm equipment, which is presently dominated by U.S. concerns. Japan currently holds a large share of the U.S. market for small tractors.[8] The future will see growing installation of automatic welding equipment and increasing use of industrial robots for welding, painting, and other high volume, difficult operations. Computers will increasingly be used for manufacturing operations and in design functions.

[1] Average annual rates of change are based on the linear least squares trends of the logarithms of the index numbers. The farm machinery and equipment industry is designated industry 352 in the *Standard Industrial Classification Manual, 1972 Edition*, issued by the Office of Management and Budget. The industry comprises establishments primarily engaged in the manufacture of farm machinery and equipment, and garden tractors and lawn and garden equipment. A technical note describing the indexes is available from the Office of Productivity and Technology, Bureau of Labor Statistics, Washington, D.C. 20212. The indexes for this industry will be updated and included in the Bureau of Labor Statistics' annual bulletin, *Productivity Measures for Selected Industries.*

[2] *Statistical Abstract of the United States, 1980* (U.S. Department of Commerce, 1980), p. 686.

[3] *1970 Census of Population, Occupation by Industry*, Vol. PC(2)-7C (U.S. Department of Commerce, 1972), pp. 281–88.

[4] Based on discussions with industry experts.

[5] *U.S. Industrial Outlook, 1974* (U.S. Department of Commerce, 1973), p. 301.

[6] *John Deere Harvester Works* (Deere and Company, 1979), p. 10.

[7] *John Deere Tractor Works* (Deere and Company, 1980), pp. 6–18.

[8] *U.S. Industrial Outlook, 1981* (U.S. Department of Commerce, 1980), p. 260.

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Productivity trends for intercity bus carriers

During 1954–79, modest advances in technology, and more package and charter service, were offset by declining passenger demand and reduced bus speeds, resulting in a 0.4-percent rise in productivity

RICHARD B. CARNES

During 1954–1979, output per employee-hour in the class I bus industry rose an average of 0.4 percent a year, a rate significantly below those of other segments of the transportation industry.[1] Class I bus carriers provide intercity service and may also provide local or charter service. Not included are those public and private transit systems that provide urban mass transportation service and do not come under Interstate Commerce Commission (ICC) reporting requirements.[2]

The 0.4-percent growth in productivity resulted from a small average annual increase in industry output of 0.1 percent combined with an average annual decline in employee hours of 0.3 percent. (See table 1.) By comparison, other transportation industries for which measures are available showed productivity increases over the same period that equaled or exceeded overall productivity growth for the private nonfarm business sector of the economy. For example, productivity in air transportation, an industry which competes for public passenger traffic, rose 6.3 percent, compared with 2.1 percent for the private nonfarm business sector. (See table 2.)

Bus operations have suffered from the recent energy shortages. Longer running times between cities have resulted from the 55-mile-per-hour national speed limit.[3] Lower speeds have increased the labor time needed to drive a given distance, and have reduced productivity. However, lower speeds have also cut fuel costs. Although total transportation travel might be expected to decline because of higher fuel costs, the relative fuel efficiency of buses enhance future demand for this mode of transportation, especially for shorter distance travel.

Productivity movements were uneven over the 1954–79 period, ranging from a 9.4 percent increase in 1962 to a decline of 11.9 percent in 1975. Generally, these changes have been in response to cyclical swings in industry output. There were three distinct trend periods. During 1954–60, output per hour rose at a 1.2-percent average annual rate. Output declined at an average yearly rate of 1.3 percent and hours dropped more sharply, by 2.6 percent. From 1960 to 1966, demand for bus service increased 4.7 percent annually, but employee hours increased at only a 1.3 percent average annual rate. The more efficient utilization of equipment and facilities, which resulted from this higher demand, raised productivity at a 3.6 percent annual rate during those 6 years. Load factors and average length of haul both increased appreciably. Load factor is the percentage of capacity actually utilized.

In the third period, 1966–79, all of the measures turned down. Productivity and output fell at an annual rate of 1.4 and 2.5 percent, respectively, while employee hours dropped 1.1 percent. Output fell in all years ex-

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cept 1967, 1974, and 1979. Since 1974, the beginning of the energy crisis and the year of the 55-mile-per-hour speed limit, productivity trends have been mixed, as table 1 indicates. There were sharp rises in 1974 and 1977, and a small gain in 1979. These were offset by a serious drop in 1975, and smaller declines in 1976 and 1978. More travelers rode buses in 1974 when fuel for private passenger cars became scarce. But when gasoline once again became plentiful in 1975, even at higher prices, bus travel declined drastically. Again in 1979, gas shortages in the second quarter helped boost industry output by 6.1 percent for the year and productivity by 0.4 percent.

Industry profile

The class I regulated bus industry comprises 43 intercity and 13 local carriers certified by the ICC. In 1978, these companies operated about 9,700 buses and had 34,000 employees. During that year, they moved 237 million passengers, and generated $961 million in passenger revenue and $175 million in freight revenue.

For most of the 15,000 communities served by intercity bus carriers, there is no other form of public transportation. Despite this, the bus passenger market has declined during the period of this study. Automobile travel represents the primary source of competition to the industry, followed by air and then train service. Expansion of charter bus and package express service has helped to offset passenger declines. (See table 3.)

Table 1. Productivity and related indexes for class I bus carriers

[1967 = 100]

Year	Output per employee-hour	Output	Employee-hours
1954	77.4	80.5	104.0
1955	80.4	79.0	98.3
1956	81.2	78.0	96.1
1957	81.6	78.3	96.0
1958	81.9	74.0	90.3
1959	84.6	74.0	87.5
1960	83.7	75.4	90.1
1961	85.3	77.1	90.4
1962	93.3	86.2	92.4
1963	94.6	86.6	91.5
1964	95.7	90.2	94.3
1965	101.2	95.0	93.9
1966	103.4	99.2	95.9
1967	100.0	100.0	100.0
1968	98.6	97.5	98.9
1969	95.7	94.2	98.4
1970	93.4	92.5	99.0
1971	91.3	86.9	95.2
1972	93.0	83.3	89.6
1973	92.5	79.8	86.3
1974	95.9	86.5	90.2
1975	84.5	78.0	92.3
1976	81.7	75.2	92.1
1977	87.1	74.7	85.8
1978	86.8	73.7	84.9
1979[1]	87.2	78.2	89.7
	Average annual rates of change		
1954-79	0.4	0.1	-0.3
1974-79	-.9	-1.9	-1.0

[1] Preliminary.

Table 2. Productivity comparison, private nonfarm business and selected transportation industries, 1954–79

Industry	Average annual rate of change		
	Output per employee-hour	Output	Employee-hours
Private nonfarm business	1.9	3.7	1.7
Transportation sector	2.7	2.9	.2
Petroleum pipelines[1]	7.5	5.6	-1.8
Air transportation[1]	6.3	11.0	4.5
Class I railroads	4.9	1.2	-3.5
Intercity trucking[1]	2.4	5.6	3.1
Class I bus carriers[1]	.4	.1	- .3

[1] Output per employee.

Intercity bus operations have the potential to provide service over a wide area because of the national highway network. Nonstop intercity buses can operate at speeds similar to those of an automobile. And, over shorter distances buses generally provide lower cost service than air or rail travel.[4] Most demand comes from short-haul passengers even though the average length of trip for intercity service has more than doubled from 62 miles in 1954 to 130 miles in 1979.[5]

When intercity bus service began in the early 1900's it was characterized by a large number of local and regional carriers. Startup costs were modest and there was rapid growth. By the 1930's, the industry had evolved into its present form, with fewer bus companies and with national systems operating over longer distances. These national networks were thought to facilitate through-service for passengers and improve bus and terminal utilization. During World War II, industry output increased rapidly due to rationing of auto parts and gasoline. Load factors during this period reached nearly 80 percent. Passenger-miles peaked in 1952 and did not reach that level again until 1967. Since 1954, few new intercity bus carrier operations have been authorized by the ICC. Presently, Greyhound and Trailways dominate the market.[6]

The bus industry is subject to both Federal and State regulation. There are restrictions on the entry of new firms, fares, route requirements, and service levels. Competition along routes is limited. Federal regulation has encouraged merger activity of carriers into larger national companies. Recently there has been an effort on the part of the ICC to liberalize entry controls and to provide greater carrier rate making autonomy. General deregulation of the industry, however, has not been formally introduced.

The sources of revenue for bus carriers have changed substantially since 1954 as table 3 indicates. Intercity and local passenger revenue has declined in relative

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terms while charter and package express services have shown significant growth. Charter service has expanded due to the increase in group travel and tourism, while package express service has benefited from the large distribution network provided by intercity buses.

The private automobile has been a major factor in the slow growth of intercity bus travel. The doubling of new car registrations since 1955 and the use of these cars for both personal and business trips impacted bus travel, and is expected to be the primary source of bus industry competition in the foreseeable future. Autos accounted for 89 percent of all intercity passenger-miles in 1954, and for 83 percent in 1979. Passenger-miles flown during this period increased their relative share of the market from 3 to 15 percent while both bus and rail passenger-miles declined.[7]

Employment and influences on productivity

Employment in the class I regulated bus industry declined from 39,000 in 1954 to an estimated 35,300 in 1979. Employment dropped steadily in the 1950's, then advanced irregularly through 1967, and thereafter generally declined again to the present level. Recent exceptions to the downward trend were in 1974–75 and again in 1979. Energy shortages resulting from the Organization of Petroleum Exporting Countries oil embargo boosted both employment and passenger service in 1974, the year that also marked the introduction of the 55-mile-per-hour national speed limit. Employment needs increased partially as a result of the decline in the number of bus miles per driver. Again in 1979, fuel shortages reversed the downward trends in both employment and passenger service.

Since 1954, there has been a change in the composition of employment. The number of equipment maintenance and garage personnel has declined from 22 to 17 percent of the work force because of reduced service requirements. Station workers, however, have increased from 11 to 19 percent of total employment, reflecting the greater demand for package express traffic. Drivers have accounted for about half of industry employment since 1954. However, more fully utilized and larger capacity buses may, in the future, reduce the percentage of drivers in the industry, by increasing the proportion of administrative and service workers. Since 1954, workers paid on a daily basis, mostly supervisory personnel, as opposed to hourly wage employees, have increased from 8 percent of total employment to 10 percent. In the intercity portion of the regulated bus industry, women represent 12 percent of the work force, up from 10 percent in 1960. By contrast, women make up 40 percent of the work force in the total private nonfarm sector.

Table 3. Revenue distribution for class I bus carriers and percent of total service, 1954 and 1978

Service	1954		1978	
	Revenue in millions	Percent	Revenue in millions	Percent
Total	$467	100	$1137	100
Passenger:				
Intercity	306	66	678	60
Local	112	24	73	6
Charter	33	7	211	19
Freight	16	3	175	15

Changes in technology associated with the bus industry have been characterized by a gradual trend toward innovation, fuel efficiency, and greater passenger comfort. Diesel-powered buses, in primary use since the early 1950's, have undergone steady advances in performance and reductions in maintenance requirements. Current-model intercity buses have a seating capacity of 47 passengers and have space for large amounts of baggage and cargo. Typically, buses are 8 feet wide and 40 feet long, and weigh 13 tons. Including resale after use by class I carriers, useful bus life is over 20 years and mileage may exceed 3 million.[8] The average number of seats for the bus fleet in 1955 was 39.1 and increased 10 percent to 43.1 by 1978. However, the seating capacity utilized during this period has remained at about 47 percent, and load factors have changed little since 1954, which helps explain the low rise in productivity in the industry.

From 1950 to 1973, average bus speeds increased from 50 to 60 miles per hour because of improved highways and urban beltways. But the introduction of the national speed limit in 1974 reduced average speeds to less than 55 miles per hour,[9] and has also slowed productivity growth.

The growth in package express and charter services, however, has aided productivity. Delivering package express while engaging in regularly scheduled passenger service has resulted in more efficient use of vehicle and driver time. Charter services have also offered significant economies of scale for bus companies. Charters typically have a 50-percent greater load factor and 100-percent longer average trip length than regular route carriers. This form of passenger service also provides economies in baggage handling, ticketing, and scheduling terminal facilities.

Reduced investment has hurt industry productivity. Since 1954, investment in plant and equipment by intercity bus carriers has declined. Buses, which presently cost about $135,000 each, account for about 80 percent of industry capital expenditures. Annual constant dollar investment dropped from $78 million in 1954 to $56 million in 1974, the latest year for which data are available. Similarly, the constant dollar stock of plant and equipment fell 18 percent, while capital investment per worker declined more than 20 percent. In contrast, gross constant dollar investment in the transportation

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sector as a whole increased more than 150 percent, while gross stocks of capital increased 35 percent.[10]

Outlook

Factors are emerging which are both favorable and unfavorable to demand and productivity growth in the bus industry. Energy and demographic variables are likely to be positive factors while negative public image and low capital investment may retard growth. Restructuring the industry has been suggested as a way to increase capacity utilization and spur productivity.

With current low rates of bus utilization, increased demand would likely result in higher load factors and enhance productivity. Several projections of growth in the bus industry for the next decade have been made. The Federal Energy Administration (now part of the Department of Energy) estimates a 25 percent growth in passenger-miles over the next decade. This projection is not altered substantially even when based on different fuel availability assumptions. The Department of Transportation (DOT) makes a similar growth projection but notes the negative effect of rising income levels and shift from longer-haul bus travel. DOT sees potential for greater demand through improved service and regulatory reform. A third projection estimates a more optimistic 40-percent growth based on assumptions of fuel shortages and restricted auto use. In contrast to these three optimistic scenarios the ICC concludes that regular route traffic will continue to experience flattened demand and market share loss.[11]

In a period of energy shortage, bus operations are likely to increase because of the comparative fuel efficiency of this mode of transportation. This was demonstrated both during World War II and in 1974 when fuel shortages existed. Given energy priorities, buses would make inroads into the use of the private automobile. Presently, diesel turbocharged engines are being introduced into service because of their potential for fuel savings and reduced emissions. Gas turbine buses now being used experimentally are able to run on non-petroleum based fuels and may aid future productivity growth because of their increased reliability.[12]

Fuel shortages would likely create more reliance on the use of buses for lower density routes to and from small towns and rural areas. Higher utilization of existing capacity in the industry would boost labor productivity. However, a recent DOT study projects that over the next two or three decades the passenger automobile will continue in its dominant transportation role because of its flexibility and tailored service.[13]

Demographic changes may also help to increase the demand for bus service, raising both load factors and productivity. The trends toward population dispersion, smaller households, and an older population are all factors which favor increased use of intercity bus service. Population dispersion reduces the availability of other forms of transportation; private cars are more cost efficient for larger families; and many older persons prefer the relative comfort and safety of bus travel.

However, a history of low productivity growth, lack of demand, and reduced profits may impair the ability of the industry to attract needed capital and enhance future performance. The ICC sees a need for changes in policy to insure a balanced transportation network. Such changes would include bus and engine design studies, similar to those conducted for air transporation and other forms of mass transit, to find ways to increase productivity. Improvements in the quality and location of bus terminals and facilities have also been recommended.[14] Because the price differential between long distance air fares and bus fares has narrowed over the years, some analysts argue that bus carriers should drop coast-to-coast service and concentrate in short-haul markets of 100 to 200 miles. Such a system could enlarge the number of daily departures and increase bus utilization from its current average of 7 hours a day to 16 hours.[15] Further advances in productivity are possible through improvements in intermodal linkages. Construction of municipal transportation terminals to serve as connectors for bus, train, and plane service could improve productivity for all of these forms of transportation.

[1] This study is based on statistics reported to the Interstate Commerce Commission for all class I motor carriers of passengers. Class I carriers are those that have 3-year average annual revenues of more that $3 million. This portion of the bus industry, as defined in the 1972 Standard Industrial Classification (SIC) manual, makes up a small part of SIC 4111 (local and suburban transit), and a more substantial part of both SIC 4131 (intercity and rural highway passenger transportation) and SIC 414 (passenger transportation charter service). Based on their major source of revenue, class I carriers have been divided by the ICC into local or intercity service. Local service is defined as transportation performed within a city or town, including service for the contiguous suburban area. Intercity service includes all transportation performed beyond the limits set for local service. Either of these carrier types may also engage in intercity, local, or charter operations.

[2] The output measure underlying the productivity series for the bus industry has been constructed using data on passenger-miles, passengers, and express freight service, combined with appropriate weights relating to labor importance. A technical note describing the methods used in the construction of the index is available upon request.

[3] Lawrence Leist, *Intercity Bus Service: Frequency and Running Time*, Report No. WP-220-04-20 (Washington, U.S. Department of Transportation, 1975).

[4] *Transportation and the Future* (Washington, U.S. Department of Transportation, 1975), p. 35.

[5] Derived by dividing revenue passenger miles by revenue passengers.

[6] *The Intercity Bus Industry: A Preliminary Study* (Washington, Interstate Commerce Commission, 1978), pp. 2–3.

[7] *Transportation facts and Trends* (Washington, Transportation

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Association of America, 1980), p. 18.

[8] *America's Most Fuel Efficient Passenger Transportation Service* (Washington, American Bus Association, 1979), p. 5.

[9] *The Intercity Bus Industry*, p. 26.

[10] See *Capital Stock Estimates for Input-Output Industries: Methods and Data*, Bulletin 2034 (Bureau of Labor Statistics, 1979).

[11] *The Intercity Bus Industry*, pp. 106–08.

[12] *America's Most Fuel Efficient*, p. 5.

[13] *Transportation and the Future*, p. 111.

[14] *The Intercity Bus Industry*, pp. 121–27.

[15] Rush Loving, Jr., "The Bus Lines are on the Road to Nowhere," *Fortune*, Dec. 31, 1978, pp. 58–64.

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Laundry and cleaning services pressed to post productivity gains

Increases in 1958–76 averaged 1.6 percent, as hours dropped twice as fast as output; wash and wear fabrics and home appliances have displaced many traditional laundries

RICHARD B. CARNES

Home laundering—devoid of yesteryear's drudgery by the use of modern machines and easy care fabrics —has increased significantly in recent times, slackening the demand for traditional, labor-intensive, family laundry and drycleaning services. This trend, in conjunction with the growth of more capital-intensive operations such as industrial launderers and linen suppliers, has resulted in a large drop in the hours worked by all persons in the industry.[1] Between 1958 and 1976, hours dropped at an average annual rate of 3.1 percent.[2] But, because the industry's output declined at about only half that rate, 1.6 percent per year, output per hour "grew" at an average annual rate of 1.6 percent over the 19-year period. Over the same period, productivity in the nonfarm business sector rose at an annual rate of 2.2 percent. On the whole, the cleaning industry's moderate productivity performance has been buoyed by gradual advances in technology and the introduction of easy-to-clean apparel.

Although the annual productivity gain in the cleaning industry averaged 1.6 percent from 1958 to 1976, growth within the period varied markedly. (See table 1.) During the 1958-65 period, for example, the average annual increase in productivity was 0.9 percent. Output grew at a 1.5-percent annual rate, while hours increased at a rate of 0.6 percent per year. From 1965 to 1970, the rate of productivity growth accelerated to 2.8 percent. However, both output and hours decreased. Output fell at a 1.4-percent yearly rate; hours fell more rapidly—about 4.0 percent per year. Textile manufacturers introduced wash and wear fabrics during these years—a development which reduced both industry demand and industry labor requirements. Many significant technological changes also contributed to the reduction in hours in the late 1960's.

During the more recent period, 1970–76, productivity growth averaged only 0.7 percent per year. A very rapid increase between 1970–73 was partially offset by a 1973–76 decline. The below-average productivity growth since 1970 was accompanied by substantial declines in both output and hours; 5.3 percent and 6.0 percent, per year, respectively. Output declines in the private business sector in 1970, 1974, and 1975 had a negative impact on the laundry and cleaning services industry. Constant dollar personal consumption expenditures for laundry and cleaning services are estimated to have declined 30 percent from 1970 to 1976.

Cleaning industry composition

The change in the demand for various types of laundry and cleaning services has changed the industry's structure. (See table 2.) Thus, although overall output dropped at an average annual rate of 1.6 percent in 1958–76, diverse movements occurred at the subindustry level. The focus of service has shifted from personal cleaning services to commercial and industrial customers.

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Despite the 1958–76 increase in real per capita income in the United States (57 percent), real per capita expenditures for family laundry and cleaning services declined by 50 percent. The sharp decline in the output of family laundry establishments has been a direct result of increased home laundering as well as easy-to-care-for fabrics. Now, families consider washers and dryers to be necessary appliances. The output of the household laundry equipment industry is estimated to have increased nearly 70 percent between 1958 and 1976. In 1975, more than 4 million home washing machines were sold, increasing market penetration to 70 percent, from 53 percent in 1960.[3] The introduction of permanent press fabrics in the mid-1960's along with more recent marketing of knit garments has further reduced the demand for family laundry services. Consequently, declines in output have occurred for nonspecialized power laundries, nonpower laundries, and drycleaning plants. In addition, there have been declines in output for garment pressing establishments, rug cleaning and repairing plants, and diaper services. From 1958 to 1972, the power and nonpower laundries declined from 32 percent of industry sales to 14 percent. Drycleaning plants lost 3 percent of the market, and garment pressing sales dropped from 7 to 5 percent over this period.

Between 1958 and 1972 (the latest year for which detailed data are available), sales by industrial laundry and linen supply establishments—which provide both rental and cleaning services to businesses and institutions—increased from 19 percent to 34 percent of total industry sales. In 1972, sales per establishment for industrial launderers and linen suppliers were 12 times greater than the industry average of $60,000. Because of the similarity in types of items to be cleaned, these establishments have introduced many standardized processing techniques. These new mass-production methods, in conjunction with more modern equipment, have greatly increased the efficiency of these typically large-scale laundries.

Table 1. Indexes of productivity, output, and hours of all persons, laundry and cleaning services, 1958–76

[1967 = 100]

Year	Productivity (output per hour)	Output	Hours of all persons
1958	83.9	86.1	102.6
1959	87.1	89.7	103.0
1960	82.7	85.1	102.9
1961	86.9	88.6	101.9
1962	86.9	88.9	102.3
1963	86.6	92.4	106.7
1964	92.7	97.0	104.6
1965	87.3	93.6	107.2
1966	92.8	98.6	106.3
1967	100.0	100.0	100.0
1968	103.4	98.2	95.0
1969	101.7	94.4	92.8
1970	99.3	87.6	88.2
1971	102.9	80.3	78.0
1972	107.0	79.7	74.5
1973	109.6	75.7	69.1
1974	107.3	69.3	64.6
1975	104.1	65.4	62.8
1976[p]	105.2	63.2	60.1

p = preliminary.

Table 2. The distribution of receipts and employment, laundry and cleaning services, 1958 and 1972

Industry segment	Percent distribution			
	1958		1972	
	Receipts	Paid employees	Receipts	Paid employees
Total	100.0	100.0	100.0	100.0
Laundry services	33.6	41.0	24.8	30.0
Power laundries	29.9	37.7	13.1	20.7
Coin-operated laundry and drycleaning	2.1	1.9	10.7	8.7
Laundries, except power	1.6	1.4	1.0	.6
Drycleaning services	38.8	39.5	35.9	43.4
Drycleaning plants	37.0	38.3	34.5	42.0
Rug cleaning and repairing	1.8	1.2	1.4	1.4
Rental services	20.7	14.5	34.7	23.0
Linen supply	12.6	8.8	18.2	15.2
Industrial launderers	6.8	4.8	15.3	6.8
Diaper service	1.3	.9	1.2	1.0
Garment pressing, alteration and repair	6.9	4.9	4.6	3.6

SOURCE: U.S. Department of Commerce. Based on 1967 Standard Industrial Classification Manual. Data are for those establishments with payrolls.

Industrial laundry establishments perform work on a contract basis, specializing in personalized work garments, wiping cloths, mats, and dust control items. Garments are identified so they can be returned after servicing to the same customer. In many cases, businesses rent these items from the laundry, which then provides service on a regular schedule. Linen suppliers work on a similar rental-contract basis, except that laundered items are not usually personalized. Linen services include the rental of apparel, towels, table and bed linen, uniforms, and a variety of other cloth items. Customers served by industrial launderers and linen suppliers include factories, restaurants, hospitals, lodging places, and schools.

Other establishments that experienced sales growth from 1958 to 1972 were coin-operated laundry and drycleaners. Because fewer new apparel require professional cleaning, the growth in commercial coin-operated laundry and drycleaning facilities has been encouraged. Coin-operated services accounted for 11 percent of industry sales in 1972—a fivefold increase since 1958. Currently there are 40,000 self-service laundry and drycleaning stores in the United States.[4]

Limited capital requirements have encouraged the growth of franchising in laundry and cleaning services. The available data on franchised laundry and drycleaning services show that average investment and startup funds totaled $71,000 in 1974. In that

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year, there were 3,700 franchise establishments with sales of $237 million—about 5 percent of total industry receipts. Three companies accounted for about 85 percent of both franchise establishments and sales.[5] To enhance sales, many franchise establishments specialize in convenient 1-day drycleaning and shirt service.

Shrinking labor input

Changes in employment among the subindustries have mirrored the changes in industry organization. From 1958 to 1976, the number of persons engaged in laundry and cleaning services fell from 688,000 to 445,000—an average annual industry decline of 2.3 percent. As with output, the largest employment losses occurred in power and nonpower laundries, drycleaning plants, and garment services. Coin-operated laundry and drycleaning establishments along with industrial laundry and linen supply establishments experienced employment growth.

Over the 19-year period, the industry average weekly hours for nonsupervisory workers declined from 38.7 to 35.9; average weekly hours for managers and the self-employed dropped from 52.9 to 46.2. As a result of the overall decreases in employment and average weekly hours, total hours fell at an average annual rate of 3.1 percent from 1958 to 1976.

The occupational composition within the laundry and cleaning service industry has also been changing. Since 1970, when detailed data first became available,[6] industry employment has been decreasing for most occupations. Only white-collar occupations have posted employment gains in recent years. Traditional blue-collar workers—craft and service workers, operatives, and laborers—lost a significant share of industry employment, dropping from 64 percent in 1970 to 58 percent in 1974. Improvements in fabric finishes have reduced demand for pressing operatives, stock handlers, laundry and drycleaning operatives, and craftworkers such as tailors, stationary engineers, and vehicle mechanics. Demand for route drivers has also fallen for family laundries as their sales have declined. Clerical workers, managers, salesworkers, and professional and technical workers have had corresponding increases in their relative share of employment, growing from 36 to 42 percent over the same 5-year period.[7]

Cleaning technology

Increased mechanization and new cleaning methods for synthetic fabrics are the primary areas of technological change in the industry.[8] Significant expenditures for larger, more efficient washers and dryers, "steam tunnels," ultrasonic drycleaning machines, high speed sorters and folders, and mechanical transfer devices reflect the demand for new technology. In addition, improvements in fabrics, detergent products, and drycleaning solvents have helped to reduce washing and drying times as well as finishing requirements.

Although data on new capital expenditures are not available for the laundry and cleaning services industry, some insights into equipment purchases have been obtained from data published for manufactured commercial laundry equipment.[9] In 1972, the commercial laundry equipment industry had sales of $219 million—more than double the 1958 sales level of $107 million. (During this period, the Wholesale Price Index for laundry equipment showed no increase.) Laundry equipment accounted for 75 percent of 1972 sales; drycleaning equipment accounted for the remaining 25 percent. The distribution of these sales has not changed since 1958. However, the type of equipment sold has changed, reflecting improved fabrics and newer, laborsaving, cleaning and drying methods. In 1958, laundry pressing equipment represented 16 percent of sales, but by 1972, had declined to just 2 percent of sales. Similarly, flatwork ironers have also declined in relative importance as "no iron" fabrics became prevalent during the period of this study. Combination washer and water extractors have advanced from 5 percent of equipment sales in 1958 to 38 percent in 1972.

An innovation which has diffused rapidly through the industry is steam tunnel finishing. After cleaning, conveyors transport hangered garments through a steam bath which relaxes the fibers and restores the garments to their original shape. They are then dried by high-velocity hot air. This equipment, when used on synthetic fabrics or blends, significantly reduces the amount of hand-operated pressing that was previously required.

The use of synthetic fabrics has also led to a gradual phasing out of older types of industrial and commercial laundry equipment. Synthetic fabrics reduce the machine cycle and process times because they are lightweight and heat resistant. Lightly soiled garments, such as office apparel, are increasingly being drycleaned or are being cleaned by dual-phase washing and drycleaning equipment.

Labor time has also been reduced by the introduction of fully automated, large-scale washers and dryers. Washer-extractors can be self-loaded, while the washing, extracting, and conditioning operations can be programmed for different load conditions to perform automatically. These automated controls have reduced operating personnel to as few as one person for this stage of processing. Labor requirements for large amounts of flatwork finishing have been significantly reduced by the use of more fully automated flatwork spreaders and high-speed folders and stackers. Electronically controlled folders can process up

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to 1,500 items per hour with various automatic width and fold combinations possible. Manual material handling for small-piece flatwork has been reduced by the use of air jets to propel items from extractors to ironers or mechanized folders.[10]

Gains in productivity have resulted from the introduction of integrated systems for material handling. Conveyors are often used for loading washing wheels and to move cleaned loads to in-line extractors, tumbler-dryers, and to the finishing department. In industrial laundries, these material handling systems are further used to automatically route personalized garments through the steam tunnels to the proper assembly area. Interest currently centers on the development of a hangered garment system which can be automatically scanned and sorted.[11]

Looking down the line

The decline in family laundries and the growth of high-volume, rental-cleaning services is expected to continue. Productivity should advance over the next decade as technological innovations continue to be introduced and diffused throughout the industry. In many cases, further improvements in textiles will result in longer lasting garments that will be even easier to clean. Polyester fabrics, for example, are being improved so they can be washed at lower temperatures. Lower temperatures and improved fabrics will reduce detergent requirements and shrinkage as well as improve color retention.

Because comprehensive delivery routes already exist, many laundry and cleaning establishments are expected to increase sales by broadening the product lines and services they offer. Rental service firms, for example, are now marketing such items as disposable rest room products and air fresheners.

More stringent environmental air and water standards have acted to reduce gains in productivity as plants divert labor and capital from the production process to meet these new demands. The impact of collecting and processing waste products and meeting fabric flammability standards has affected plant operating methods and equipment needs. In some cases, customers must be screened to insure that their garments will not cause unacceptable levels of water and air pollution. This has led to industry requirements for sophisticated ventilation and filtration equipment along with hot water and heat recovery systems. As new technology is developed to meet these environmental and health needs, future trends in productivity and output could be enhanced. For example, "sniffer" units which help reduce solvent emissions into the air can also be used to reclaim and recycle usable solvent, thus increasing operating efficiency. Demand in some segments of the industry could increase as establishments which currently launder their own textiles turn to commercial launderers and cleaners who have developed the equipment and expertise needed to meet stricter environmental standards.

[1] The study covers paid and unpaid persons (including paid employees, partners, proprietors, and unpaid family members) working in laundry and cleaning service establishments. The industry is designated as laundry, cleaning, and garment services, SIC 721, in the 1972 Standard Industrial Classification (SIC) Manual. SIC 721 is composed of 9 subindustries: 7211, Power Laundries Family and Commercial; 7212, Garment Pressing and Agents for Laundries and Dry Cleaners; 7213, Linen Supply; 7214, Diaper Service; 7215, Coin-operated Laundries and Drycleaning; 7216, Drycleaning Plants Except Rug Cleaning; 7217, Carpet and Upholstery Cleaning; 7218, Industrial Launderers; 7219, Laundry and Garment Services not elsewhere classified.

[2] All average annual rates of change are based on the linear least squares trend of the logarithms of the index numbers. Updated indexes will appear in the annual BLS Bulletin, *Productivity Indexes for Selected Industries.*

[3] See "1976 Statistical and Marketing Report," *Merchandising,* March 1976.

[4] Information provided by the National Automatic Laundry and Cleaning Council.

[5] Andrew Kostecka, *Franchising in the Economy, 1974–76* (Washington, Department of Commerce, 1976), p. 71.

[6] Bureau of Labor Statistics, unpublished data for 1970–85, National Industry Occupational Matrix.

[7] Ibid.

[8] For an earlier study of technology in this industry, see Mary L. Vickery, "New technology in laundry and cleaning services," *Monthly Labor Review,* February 1972, pp. 54–59.

[9] Bureau of the Census, Census of Manufacturers, 1972 Industry Series: *Service Industry Machines and Machine Shops,* MC72 (2)–35G, 1975

[10] Vickery, *New technology,* p. 56.

[11] "The Year 75–76 in Review," *Industrial Launderer,* November 1976, p. 7.

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Cyclical behavior of productivity in the machine tool industry

Productivity growth was slow during 1958–80, partly because of the industry's tendency to retain skilled workers during cyclical downturns; computers and other electronic equipment aided production, but diffusion of such innovations has been slow

JOHN DUKE AND HORST BRAND

Output per employee-hour in the machine tool industry rose at an average annual rate of 1.1 percent over the 1958–80 period—significantly below the 2.8-percent rate for manufacturing.[1] A combination of factors slowed productivity in the machine tool industry, including the tendency of machine tool firms to keep highly skilled workers on the payroll, even when output fell during cyclical slowdowns, and the slackened demand for capital goods after the mid-sixties. However, the slowdown was moderated by technological advances in the manufacture of machine tools, as well as by high rates of productivity improvement in periods of cyclical recovery.

Until 1966, productivity in the machine tool industry rose at a high annual rate, but thereafter the rate declined for several years. Its subsequent recovery remained incomplete—the high levels of the mid-sixties were not reattained. The recovery was again interrupted by a slump in 1974; it resumed in 1977, continuing to 1979, but even then productivity did not top its 1966 peak. (See table 1.) The cyclical behavior of productivity in the industry and in manufacturing is shown in the following tabulation (average annual changes in percent):

	Machine tools	*Manufacturing*
Upswings:		
1958–59	23.1	4.8
1961–66	5.6	4.4
1971–74	7.8	2.9
1976–80	2.4	0.9
Downswings:		
1959–61	-2.0	1.7
1966–71	-4.2	2.0
1974–76	-5.2	3.7

Productivity in both the metal cutting and metal forming segments of the industry paralleled the cyclical patterns shown above, although amplitudes differed. Productivity improvement averaged 1.5 percent annually in metal cutting (which accounts for three-fourths of total industry employment), and 0.1 percent in metal forming. Upswings in productivity were more pronounced in metal cutting than in metal forming; downswings were more pronounced in metal forming. In metal cutting, productivity dropped in 8 of the 22 years examined (table 2); in metal forming, in 12 (table 3). The drops were only in part associated with general business cycles; they occurred in years of economic expansion as well as during contractions.

Output recovery slow in the seventies

The machine tool industry manufactures cutting tools for boring, drilling, gear cutting, grinding, and milling

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machines and lathes, as well as forming tools such as punching, shearing, bending, and forming presses. These tools are usually shipped as units, that is, as single-purpose machines, but their basic features may also be combined into "machining centers." The machine tools may be equipped with manual controls or with programmed numerical controls which require little labor by users. Machine tools are not mass produced, although they may make mass production processes possible in user industries. Rather, the parts and components of a finished machine tool are usually made in relatively small batches, and require comparatively large amounts of labor.

Output in the machine tool industry rose at an average annual rate of 1.6 percent between 1958 and 1980, compared with 3.8 percent for manufacturing. Underlying the long-term trend were cyclical swings of considerable amplitude. The metal cutting and metal forming segments of the industry traced similar cyclical patterns. (See table 4.)

The following tabulation shows the cyclical behavior of output in the machine tool industry and in manufacturing, 1958–80 (average annual changes in percent):

	Machine tools	*Manufacturing*
Upswings:		
1958–59	25.7	11.7
1961–66	14.6	8.2
1971–74	17.2	5.9
1976–80	9.1	2.9
Downswings:		
1959–61	-1.1	0.2
1966–71	-11.1	1.0
1974–76	-14.1	0.9

Recoveries in machine tool output during the seventies were less vigorous than they had been in the 1958–59 and 1961–66 upswings. Slumps were deep. Long-term factors contributing to the comparative weakening of output included the volatility in the demand for producers' durable equipment. Following 12 percent annual increases in the 1961–66 period, growth in demand for producers durable equipment contracted to 2 percent a year for 1966–71. Demand rebounded at an 11-percent annual rate in the early seventies, declined by 3 percent annually over the 1974–75 period, then recovered to a 10-percent annual growth rate in 1976–79. Even so, the long-term growth in the demand for producers' durable equipment slackened in the seventies (compared with the demand in the sixties) from an average annual growth rate of 8.1 percent in 1958–68 to 4.8 percent in 1968–79. However, the levels of the sixties were consistently exceeded subsequently—contrary to the situation in machine tool output and productivity. Thus, the relation between producers' durable output and machine tool output clearly weakened.

Table 1. Productivity and related indexes for the machine tool industry, 1958–80

[1977 = 100]

Year	Output per employee-hour	Output	Employee-hours
1958	71.5	63.0	88.1
1959	88.0	79.2	90.0
1960	84.7	82.8	97.8
1961	84.5	77.4	91.6
1962	88.5	88.0	99.4
1963	90.1	93.0	103.2
1964	99.9	112.3	112.4
1965	101.4	125.3	123.6
1966	111.7	156.1	139.8
1967	101.8	149.9	147.3
1968	97.9	137.6	140.5
1969	100.1	137.8	137.7
1970	91.7	112.0	122.1
1971	87.9	81.4	92.6
1972	98.0	91.2	93.1
1973	107.3	116.3	108.4
1974	109.4	127.4	116.5
1975	103.0	109.1	105.9
1976	98.4	93.9	95.4
1977	100.0	100.0	100.0
1978	102.6	111.8	109.0
1979	107.0	125.9	117.7
1980	106.9	129.1	120.8
	Average annual rates of change (in percent)		
1958–80	**1.1**	1.6	0.5
1975–80	**1.3**	5.4	4.0

During the seventies, a number of metalworking industries representing key markets for machine tools registered comparatively slower growth or actual declines in output. For example, production of motor vehicles after the mid-sixties rose at only about one-half the rate for 1959–66. Similarly, output growth of construction machinery contracted. Steel output, which had advanced at more than 5 percent a year until 1966, became stagnant thereafter, then fell, as did output of electric motors and generators, nonferrous metals, household appliances, and household furniture.[2]

Furthermore, expenditures for machine tools dropped as a proportion of total equipment expenditures by manufacturing firms. In the sixties, such expenditures accounted for 11 percent of the total, in the seventies, for only 9 percent. Moreover, imports increasingly displaced domestic machine tools. In the sixties and up to 1973, machine tool imports averaged well under 10 percent of total U.S. machine tool units purchased; thereafter, the volume of machine tool imports soared, and by 1978, they accounted for 21 percent of total units purchased.[3] In contrast, exports did not rise markedly relative to output—exports represented 8 percent of machine tool units purchased in the sixties and about 10 percent in the seventies.

Still another factor underlying slackened output of machine tools has been the rapid rise in their productive capacity. (This factor will be explained more fully later in this article.) A study of more than 350 companies

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showed that reduced machining time for numerically controlled (or programmed) machine tools ranged from 35 percent to 50 percent.[4] According to the *American Machinist's* periodic inventories of metalworking equipment, the "population" of machine tools in use did not change significantly between 1963 and 1976–78, but the output of the metalworking industries using them generally increased, indicating rising productive capabilities of the machine tools, particularly those equipped with numerical controls.[5] Some engineering authorities maintain that numerically controlled machine tools permit "drastically reduced" handling time because they eliminate the separate operations of transferring and clamping and unclamping.[6]

The relative importance of all categories of machine tools lessened during 1958–80, except lathes, drilling machines, and machining centers. (Machining centers combine the separate operations of boring, drilling, and milling units.) Most of the shift toward machining centers occurred after 1968, when the diffusion of numerical control, an essential component of machining centers, began to accelerate. In 1978, the number of machining centers shipped was half again as high as in 1968. During that decade, the number of numerically controlled metal cutting machine tools shipped more than doubled and the number of metal forming machine tools rose by 14 percent.

The diffusion of numerically controlled machine tools has remained limited, however. According to the *American Machinist's* 1976–78 inventory of metalworking equipment, only 2 percent of the machine tools in the United States were numerically controlled, and only 7 percent of machine tools 10 years old or less were numerically controlled.[7]

Table 2. Productivity and related indexes for metal cutting, 1958–80

[1977 = 100]

Year	Output per employee-hour	Output	Employee-hours
1958	67.6	58.1	85.9
1959	83.2	74.2	89.2
1960	81.5	81.0	99.4
1961	80.0	72.7	90.9
1962	83.2	83.0	99.7
1963	84.3	88.4	104.9
1964	94.9	109.2	115.1
1965	98.7	124.8	126.4
1966	107.8	154.7	143.5
1967	98.0	150.6	153.6
1968	95.7	139.8	146.1
1969	97.5	139.0	142.5
1970	89.5	107.2	119.8
1971	85.5	75.2	88.0
1972	94.8	83.9	88.5
1973	105.5	108.6	102.9
1974	108.9	122.3	112.3
1975	102.9	107.5	104.5
		92.5	95.1
1976	97.3		
1977	100.0	100.0	100.0
1978	103.6	113.7	109.7
1979	109.7	130.6	119.0
1980	111.2	138.3	124.4
	Average annual rates of change (in percent)		
1958–80	1.5	1.9	0.5
1975–80	2.3	7.2	4.8

Table 3. Productivity and related indexes for metal forming, 1958–80

[1977 = 100]

Year	Output per employee-hour	Output	Employee-hours
1958	83.6	78.4	93.8
1959	102.8	95.1	92.5
1960	94.5	88.9	94.1
1961	98.0	91.9	93.8
1962	105.7	104.3	98.7
1963	108.4	107.5	99.2
1964	115.5	122.2	105.8
1965	109.3	127.1	116.3
1966	123.1	160.8	130.6
1967	112.7	147.9	131.2
1968	103.9	131.7	126.8
1969	107.0	134.3	125.5
1970	98.5	126.2	128.1
1971	95.7	99.6	104.1
1972	107.5	112.1	104.3
1973	114.1	139.2	122.0
1974	111.9	142.5	127.4
1975	104.0	114.1	109.7
1976	101.7	98.1	96.5
1977	100.0	100.0	100.0
1978	99.9	107.2	107.3
1979	100.4	114.8	114.3
1980	95.2	106.1	111.5
	Average annual rates of change (in percent)		
1958–80	0.1	0.7	0.6
1975–80	−1.4	0.5	1.9

The output capacity of metal forming machine tools, like that of metal cutting tools, significantly increased during 1958–80, tending to retard demand and, hence, output growth. For example, the size of presses used in the automotive and appliance industries—which account for the lion's share of the demand for presses—has increased such that, in the past 15 years, it tended to be four times greater than that in the preceeding 35 years.[8] Changes of dies, which used to require 30 to 40 minutes, now take only 90 seconds—hence, long production runs are no longer needed to justify die changes.[9] Numerical controls have been applied to operations such as bending—now tube benders perform more than 30 types of bends.[10]

Employment concentrated in metal cutting

In 1980, employment in the machine tool industry numbered about 108,000 persons, with about one-quarter of them in metal forming establishments. Employee-hours rose quite slowly over the 1958–80 period (0.5 percent, compared with 1 percent in manufacturing) but, like productivity and output, were characterized by pronounced cyclical swings. The cyclical volatility of employee-hours in the machine tool industry, compared

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with manufacturing, is illustrated in the following tabulation (average annual change in percent):

	Machine tools	*Manufacturing*
Upswings:		
1958–59	2.2	6.6
1961–66	8.5	3.6
1971–74	8.8	2.9
1976–80	6.6	1.9
Downswings:		
1959–61	0.9	-1.4
1966–71	-7.3	-1.0
1974–76	-9.5	-2.6

Although recoveries in employee-hours in the seventies were about as strong as in the sixties, the levels of the mid-sixties were not reached. In 1980, employee-hours were one-fifth below those of the sixties. Employment was less affected by cyclical swings and was 17 percent lower in 1980 than in 1967, the peak year of the 22-year period. The metal cutting and metal forming segments of the industry displayed comparable cyclical patterns in employee-hours. (See table 4.)

The cyclical declines in output and, hence, in employee-hours, probably aggravated the industry's perennial shortages of skilled help when business picked up again. In part, these shortages were met through overtime work. Following are relatives of overtime hours in the metal cutting and metal forming segments of the machine tool industry (overtime hours in manufacturing = 100):

Metal cutting:			
1958	60	1969	150
1959	122	1970	110
1960	144	1971	55
1961	113	1972	117
1962	143	1973	168
1963	157	1974	191
1964	181	1975	138
1965	175	1976	103
1966	203	1977	154
1967	206	1978	178
1968	131	1979	188
		1980	211
Metal forming:			
1972	134	1976	129
1973	189	1977	140
1974	206	1978	172
1975	154	1979	191
		1980	161

In only 2 years (1958 and 1971) of the review period did overtime in metal cutting fall below the manufacturing average. In all other years it was above, and often was half again to twice as high. Metal forming (for which pertinent data exist only since 1972) showed the same overtime pattern.

The number of nonproduction workers in metal cutting rose more rapidly than that of production workers, 0.9 percent per year versus 0.3 percent. There were 43 percent more nonproduction workers in 1980 than in 1958, and 38 percent more production workers, although employment of both groups was below the 1967 peak. In metal cutting, the proportion of nonproduction workers remained above 30 percent of total employment during the period, reflecting the continued importance of engineers, designers, and other leading personnel. The proportion of women also rose, from 9 to 13 percent of total employment, but was still far below the manufacturing average of 31 percent.

In metal forming, the number of production workers showed no change on average; in contrast, nonproduction workers rose 2.6 percent—from 31 percent of total employment in 1958 to 34 percent in 1980. Occupational data are not available for the machine tool industry, but are available for the metal working machinery group of industries, of which the machine tool industry accounts for about 30 percent of employment. The occupational mix in the machine tool industry is unlikely to differ very much from that in metalworking.

In 1978, metalworking machinery had an unusually high percentage of craft and kindred workers—nearly one-third of its employment, compared with just under one-fifth for manufacturing. As might be expected, the proportion of metal craftworkers and machinists considerably exceeded the manufacturing average. Operatives accounted for a smaller proportion of employment in metalworking than in manufacturing (33 percent versus 43 percent), although the proportion of semiskilled workers in metalworking was nearly three times higher (15 percent versus 6 percent). As for professional and technical workers, the employment differences were small between the metalworking and all manufacturing industries—9 percent versus 10 percent—and this was true for other white-collar categories. However, from 1970 forward, the rise in the number of professional and technical workers was almost three times greater in metalworking than in manufacturing—14 percent versus 5 percent—reflecting the growing relative importance of electronic technicians and computer and numerical control specialists and programmers.

Technology diffused gradually

A number of important innovations have been adopted in the manufacture of metal cutting and metal forming machine tools, but diffusion among machine tool producers has been slow—slower than among industries which apply the innovations in mass production. As will be documented, this slowness is related to the predominance of small firms which produce small batches of frequently complex machinery and components. The machine tool industry is labor-intensive, relative to most manufacturing industries, as indicated by the high ratio of payroll to value added. Over the 1958–77 period, this ratio averaged 58 percent for metal cut-

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Table 4. Cyclical behavior of productivity in the machine tool industry and its components, 1958–80

[Average annual rates in percent]

Period	Output per employee-hour			Output			Employee hours		
	Machine tools	Metal cutting	Metal forming	Machine tools	Metal cutting	Metal forming	Machine tools	Metal cutting	Metal forming
1958–80	1.1	1.5	0.1	1.6	1.9	0.7	0.5	0.5	0.6
Upswings:									
1958–59	23.1	23.1	23.0	25.7	27.7	21.3	2.2	3.8	−1.4
1961–66	5.6	6.3	3.8	14.6	16.1	10.6	8.5	9.2	6.5
1971–74	7.8	8.7	5.4	17.2	18.7	13.8	8.8	9.2	7.9
1976–80	2.4	3.7	−1.3	9.1	11.3	3.0	6.6	7.4	4.3
Downswings:									
1959–61	−2.0	−1.9	−2.4	−1.1	−1.0	−1.7	0.9	0.9	0.7
1966–71	−4.2	−4.0	−4.6	−11.1	−12.4	−7.8	−7.3	−8.8	−3.4
1974–76	−5.2	−5.5	−4.7	−14.1	−13.0	−17.0	−9.5	−8.0	−13.0

ting establishments, and 60 percent for metal forming establishments, compared with 52 percent for nonelectrical machinery, 52 percent for transportation equipment, and 47 percent for all manufacturing. The mass production techniques made possible by machine tools generally cannot be used in building them, although significant improvements in small-batch production processes have resulted from some basic technological advances.

By far the most important development in machine tool technology has been the evolution of numerical control. In fact, numerical control has reshaped machine tool technology, and continues to transform it. Essentially, numerical control made multifunction machine tools possible (exemplified by the machining center, discussed earlier). According to *Iron Age,* numerical control tools have been decisive in achieving "the critical balance . . . . in machine construction and rigidity, horsepower, speed and feed ranges, standard tooling and management control over the machine cycle and operation."[11] Numerical control was first applied in the manufacture of machine tools in the mid-fifties, but certain innovations were required to lower its cost and, thus, spur adoption by the smaller machine tool firms. Although these innovations have occurred, their impact on productivity was retarded by the severe cyclical downturns in the industry's business in the early and middle seventies.

Numerical control is a method whereby metal cutting (and to some extent metal forming) machine tools are controlled by instructions which are programmed and then punched on a tape. Information from the tape is converted into instructions which position the tools with respect to the workpiece; no templates, drill jigs, or stops are used and manual operation is not necessary. (The operator can service more than one numerically controlled machine tool.) A feedback mechanism adjusts (or stops) the tool's movement if programmed distance does not adhere to commanded tolerance, and stops it when the process is completed.[12]

Numerical control has always required drives which would ensure that performance followed command. Hydraulic servomechanisms are still used for this purpose. In the late sixties, however, silicon-controlled rectifiers (which are solid-state devices) were introduced; these, together with improvements in the control motor, made possible much higher degrees of accuracy in machining work. Also, tool life was extended as gear transmission, hand wheels, and clutches were eliminated.[13] Perhaps most important, the substitution of transistors, and later of integrated circuits, for electric relays reduced the number of control components by up to 90 percent, and the amount of wiring by up to 80 percent.[14] These developments slashed costs, and also allowed less highly trained personnel to program the machines. Thus, improved control mechanisms gave impetus to the diffusion of numerical controls.

Numerical controls accelerated the consolidation of machine tool production—as well as the production of metalworking equipment—into machining centers. Machining centers are basically milling machines which also drill, ream, bore, tap, and so forth. In machining centers, complex shapes may be made by mounting cutting tools of varying sizes and power configurations on a single spindle. The cutting tools then are automatically changed by transfer arms, which also store the tool. These automatic tool changes take only a few seconds; formerly several minutes of an operator's time were required.[15] Machining centers also eliminate the need to design, build, and store the jigs and fixtures needed by single-purpose machines.[16]

Single-purpose machines also have been much improved by numerical controls. For example, numerically controlled boring machines have reduced downtime for loading and unloading by up to 30 percent.[17] Numerical control applied to grinding machines often halves layout time; programmable electronic wheel feed and wheel retraction have been developed which reduce labor time and enhance precision. The design of hobs for gear cutting has been subjected to computer calculation, saving cutting time.[18]

Cutting tool materials have become harder, permit-

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ting increased cutting speeds (albeit at the cost of requiring heavier, more powerful machines). Tungsten carbide which replaced high-speed steel in 1929 was in turn supplanted by ceramic materials and polycrystalline diamond-tipped tools. Until 1900, cutting speeds ran up to 25 feet per minute; high-speed steel tools averaged 90 feet per minute; tunsten carbide, 150 feet per minute; ceramic materials, 650 feet per minute; and polycrystalline diamond-tipped tools can cut several thousand feet per minute. Meanwhile, the older cutting materials have been improved—for example, steel tools are hardened by cobalt and continue to be widely used. Naturally, the high speeds enlarge the machine tool's output capacity.[19]

Metal cutting tools predominate over the use of metal forming tools in the manufacture of either type of machine tool. Thus, technological improvements in metal forming tools and increases in their output capacity have, of course, greatly benefited those who use the tools intensively, but have only marginally affected productivity of those who produce the tools.[20]

Computers are used in tandem with or incorporated into numerically controlled machine tools where reliability or control is crucial (as in the machining of frames for aircrafts), or where minimizing of downtime is essential. The recent trend has been toward relatively small computers interfacing with individual machines, rather than a single computer controlling a number of machines.[21] The computer has also been used in production management, as well as in the design of machine tools, significantly reducing labor requirements of engineering and drafting personnel. Conventionally, engineers and aides graphed the design for a machine tool on drawing boards, according to a customer's specifications; corrections usually required redrawing of all or most of the design to preserve proportionalities. Now, computers do the corrected redrawing, cutting the time required for such corrections. This so-called interactive graphics has permitted a 4-fold increase in the designer's productivity. Memory storage of given designs further aids productivity.[22]

Relatively old capital stock

The machine tool industry, although vital for the expansion and modernization of industrial machinery, has spent relatively little for its own plant and equipment. During the review period, the long-term growth in such spending was significantly below that for all industries. One of the results has been that the average age of equipment in the machine tool industry is well above that in all other metalworking industries.[23]

According to 1977 census data, plant and equipment expenditures per employee in metal cutting machine tools represented only 52 percent of the comparable figures for all manufacturing; for metal forming machine tools, the ratio was 40 percent. Fixed assets per worker in metal cutting and metal forming were 77 percent and 81 percent of the manufacturing average in 1976. Moreover, the long-term growth in the industry's expenditures for new plant and equipment, expressed in constant dollars, averaged 2.7 percent annually between 1958 and 1978—compared with 4.6 percent for all manufacturing industries. However, these long-term trend indicators obscure significant cyclical changes. Following are average annual rates of change in expenditures (in constant dollars) for new plant and equipment in the machine tool industry and in all industries, 1958–78:[24]

	Machine tools	*All industries*
Upswings:		
1958–59	2.3	7.3
1961–66	29.5	10.2
1971–74	28.0	7.3
1976–78	16.7	10.5
Downswings:		
1959–61	-9.5	2.4
1966–71	-18.0	1.4
1974–76	-9.6	-3.8

Cyclical patterns in the real value of the industry's capital outlays parallel those for productivity, output, and employee-hours. Even though capital outlays were strong during the upswings of the seventies, they did not reattain the levels of the sixties. In the 1976–78 upswing, the outlays were nearly one-third below those of the mid-sixties, while outlays for all industries were nearly a third higher.

The machine tool industry's low levels of expenditures for plant and equipment are reflected in the relatively high average age of its equipment. According to the *American Machinist,* 23 percent of the industry's machine tools were less than 10 years old in 1976–78, compared with 31 percent for all metalworking industries; 37 percent were 10 to 19 years old, compared with 35 percent for all metalworking and 40 percent were more than 20 years, compared with 34 percent.

The *American Machinist's* periodic inventories suggest that user industries tend to delay replacement of aging machine tools. On average, only 31 percent of machine tools in service in all metalworking industries were less than 10 years old in 1976–78, compared with 36 percent in 1968 and in 1963; 34 percent were more than 20 years old in 1976–78, compared with 23 percent in 1968 and 21 percent in 1963.[25]

The rising average age of machine tools may have been offset to some degree by the high proportion of parts and rebuilt machine tools shipped by toolmakers. Parts for metal cutting tools and rebuilt machine tools accounted for 19 percent of total shipments in 1976,

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compared with 14 percent in the late sixties. Parts for metal forming tools and rebuilt machinery constituted 33 percent of shipments in 1976, compared with 20 percent in the late sixties. The proportion rises in periods of slack business, but the rise may, in part, indicate intensified efforts to retrofit and upgrade aging machine tools, in lieu of purchasing new machines.

However, the high average age of equipment in the machine tool industry may have been partially offset through the replacement of worn-out parts, or by the rebuilding of machines along more up-to-date lines. Furthermore, the industry has an above-average proportion of numerically controlled machine tools—nearly 4 percent of its tools are numerically controlled, compared with 2 percent for all metalworking industries. Because numerically controlled machine tools are generally under 15 years old, they probably represent at least 6 percent of the industry equipment that has been in service less than 20 years, and surely a much larger proportion of its total output capacity.

Industry structure. The structure of the machine tool industry does not differ much from that of manufacturing as a whole. In 1972, the latest year for which data are available, the four largest of the nearly 900 companies making metal cutting machine tools accounted for 25 percent of the industry's total employment, 22 percent of its value of shipments, and 30 percent of its capital expenditures. In metal forming, concentration was slightly less. The 50 largest metal cutting companies, representing 10 percent of all establishments in the industry, accounted for three-quarters of employment, value of shipments, and capital expenditures. Trends in value added per employee by employment size class of establishment suggest that productivity has risen at a somewhat higher rate in establishments with 100 or more employees than in smaller establishments.

Accelerated demand may aid diffusion

Industry observers generally expect that demand for machine tools will remain strong. Whether this means that skilled labor shortages will persist is arguable. Skilled workers who have been laid off because of slow business in key metalworking industries such as automobiles may be available. But, because average hourly wages in these industries are often higher than those in machine tools, it may be difficult for the machine tool industry to attract such workers. Hence, incentives for technological advances in the machine tool establishments may remain fairly strong. Therefore, unless the machine tool industry also suffers from slow business, productivity should improve at somewhat higher rates than the long-term rates reported here.

Continued high levels of demand for machine tools are anticipated from automotive and aircraft manufacturers, and from manufacturers in other metalworking industries requiring more "flexible" technology for small-batch production.[26]

For the next several years, the automotive industry will be retooling for the production of smaller, more energy-efficient vehicles, at an estimated cost of $60 billion. Undoubtedly, this will strain machine tool manufacturing capacity. However, in the long run, demand for machine tools from the automotive industry is likely to slacken because of the prospective reduction in the number of automobile models.[27] Similarly, the aircraft industry may replace about one-half of its 6,000 commercial air carriers, some of which were placed in service 20 years earlier. New configurations of air frames will be needed which conform with mandated requirements to reduce noise levels and fuel consumption. Therefore, the aircraft industry will need more cost-effective machine tools.[28] Metalworking firms generally have become concerned with more efficient production of small batches of parts and components; their interest in automated batch manufacturing systems is likely to intensify. In such systems, electronically-controlled assemblages of machine tools are linked by material-handling equipment so as to convert a system of discrete parts manufacturing into one of continuous (or nearly continuous) processing.[29] Automatic-batch manufacturing systems have been increasingly used in the construction machinery industry.[30]

The building of craftworkers skills into the machine began when Eli Whitney constructed musket-making machines in the early 19th century.[31] The need "to build the skill in the machine" arose partly from the perennial shortage of craftworkers (which often resulted in unskilled workers operating complex equipment) and partly from the increased precision demanded of machine tools. Quite possibly, the diffusion of numerically controlled machine tools will accelerate the trend "to build the skill in the machine" in the eighties. As noted in the discussion on occupational patterns, this trend has affected the machine tool industry less than most other industries. This occupational pattern has been projected to persist: in 1990, the Bureau of Labor Statistics projects that 31 percent of metalworking machinery industry employees will be skilled craftworkers (only slighly below the 1980 proportion), compared with 20 percent for all manufacturing. Thus, the Bureau's projections implicitly assume that skill needs in the metalworking industry will change little; and that in the machine tool industry, it will continue to be difficult, at times even infeasible, to build the skill of craftworkers into machine tools.

Nevertheless, the diffusion of numerically controlled machine tools will probably accelerate under the spur of

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strong demand (which justifies the investment) and recurrent labor shortages. Also, as new generations of managers, engineers, and technicians enter the industry, numerical control and other computer-related methods will be more widely applied. The costs of these systems are likely to fall; hence, they will become more widely diffused.[32]

Although some manufacturing industries use unmanned machining systems,[33] demand is likely to be small for them. It would not be feasible financially for the machine tool industry to use such complex systems —downtime being very expensive.[34] Thus, the "unmanned factory" cannot be envisioned *for* the machine tool industry; its manufacture *by* this industry, however, can be.

It is said that automotive engine plants rely heavily on the machine tool industry for advances in their production equipment.[35] In turn, the machine tool industry increasingly relies on electronics and the computer for its technological advances. Electronics and computers will likely be dominant in machine tool production in the years ahead.

[1] The machine tool industry consists of machine tools, metal cutting types (SIC 3541) and machine tools, metal forming types (SIC 3542) as designated in the Office of Management and Budget's 1972 *Standard Industrial Classification Manual.*

[2] In this article, metalworking industries conform with those included in the *American Machinist* inventory of metalworking equipment and include the furniture industry (SIC 25); primary metals industry (SIC 33); fabricated metal products industry (SIC 34); nonelectrical and electrical machinery industries (SIC 35 and 36); transportation equipment industry (SIC 37); precision instrument industry (SIC 38); and miscellaneous manufactures industry (SIC 39).

According to BLS data, average annual rates of change of the output of some major metalworking or other major machine tool using industries moved as follows:

Industry and SIC number	*Output*		
	1959–66	*1966–73*	*1973–79*
Household furniture, 251 . .	4.8	4.5	1.9
Steel, 331	5.1	0.7	–0.8
Copper rolling and drawing, 3351	7.2	–0.1	–0.5
Aluminum rolling and drawing, 3353,4,5.	9.4	6.7	2.2
Metal cans, 3411.	2.8	3.9	[1]0.7
Construction machinery, 3531	5.8	3.3	1.5
Electric motors and generators, 3621	7.4	–1.2	1.4
Household appliances, 3631,2,3,9	7.6	2.8	2.7
Motor vehicles, 371	9.1	4.8	4.8

[1] 1973–78

[3] *Metalworking Machinery,* Current Industrial Reports, Series MQ 35–W (U.S. Department of Commerce, various issues).

[4] Donald N. Smith and Larry Evans, *Management Standards for Computers and Numerical Controls* (University of Michigan, 1977).

[5] "Fewer, more productive machines: The 12th American Machinist Inventory of Metalworking Equipment, 1976–78." *American Machinist,* December 1978, pp. 133–43.

[6] L. Mackay, and R. Leonard, "NC and Conventional Manufacturing Systems—A General Comparison." *Proceedings of the 18th International Machine Tool Design and Research Conference* (London, The Macmillan Press, 1978), pp. 651 ff.

[7] *American Machinist,* December 1978.

[8] "The Machine Tools That Are Building America," *Iron Age,* Aug. 8, 1976, p. 269.

[9] *Iron Age,* Aug. 8, 1976, p. 271.

[10] *Iron Age,* Aug. 8, 1976, p. 274.

[11] *Iron Age,* Aug. 8, 1976, p. 165.

[12] *McGraw-Hill Encyclopedia of Science and Technology,* vol. 13, (McGraw Hill, 1977), p. 692.

[13] *Iron Age,* Aug. 8, 1976, p. 166.

[14] *Machine Design.*

[15] *Iron Age,* Aug. 8, 1976, p. 200.

[16] *Iron Age,* Aug. 8. 1976, p. 174.

[17] *Iron Age,* Aug. 8, 1976, p. 189.

[18] *Iron Age,* Aug. 8, 1976, p. 256.

[19] L.T.C. Rolt, *A Short History of Machine Tools* (Cambridge, The M.I.T. Press, 1965), p. 223. *American Machinist,* Sept. 2, 1974.

[20] Information obtained from an industry representative.

[21] Agis Salpukas, "Computerizing machine tools," *The New York Times,* June 5, 1980, p. D2.

[22] Information obtained from industry representatives.

[23] *American Machinist,* December 1978.

[24] Expenditure data for the machine tool industry available to 1978 only. Data are from the *1980 Economic Report of the President.* Deflators are for private nonresidential fixed investment.

[25] Of the leading industrial countries, the United States has the smallest percentage of machine tools in service less than 10 years. Even so, the actual number of such tools in the United States was 803,000 in 1976–78, nearly half again as many as in Germany and Japan. (See *American Machinist,* December 1978.)

[26] *Manufacturing Technology—A Changing Challenge to Improve Productivity* (Washington, General Accounting Office, 1976).

[27] "A paucity of new models means layoffs and toolmaking plant closings, while continual changes, such as those that occurred during the mid-sixties, signal exciting mechanical challenges, full work force utilization, and extended overtime premiums . . ." H.E. Arnett and D.N. Smith, *The Tool and Die Industry, Problems and Prospects* (Ann Arbor, The University of Michigan Graduate School of Business Administration, 1975), p. 18. Estimated retooling cost from *Facts and Figures 1980,* (Detroit, Motor Vehicle Manufacturers Association 1980), p. 5.

[28] *Iron Age,* Mar. 17, 1980, p. 37.

[29] *Iron Age,* Nov. 20, 1978, p. 75 ff.

[30] John Duke, "Construction machinery industry posts slow rise in productivity," *Monthly Labor Review,* July 1980, pp. 33–36.

[31] *A Short History of Machine Tools.* See especially pp. 147–48, and 223. See also David F. Noble, "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools," in Andrew Zimbalist, ed., *Case Studies on the Labor Process* (New York, Monthly Review Press, 1979), pp. 18–50.

[32] A. Harvey Belitsky, "Metalworking Machinery," in *Technology and Labor in Five Industries* (Bureau of Labor Statistics, forthcoming).

[33] *Iron Age,* Dec. 17, 1979.

[34] *American Machinist,* December 1979, p. 82.

[35] William J. Abernathy, *The Productivity Dilemma, Roadblock to Innovation in the Automobile Industry* (Baltimore, The Johns Hopkins Press, 1978), p. 61.

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Nonwool yarn mills experience slow gains in productivity

During 1958–80, new equipment and techniques aided productivity growth; although the 2.3-percent rate of increase was less than for manufacturing as a whole, it accelerated during the last 8 years of the period

JAMES D. YORK

As measured by output per employee hour, productivity in the nonwool yarn mill industry increased at an average of 2.3 percent during 1958–80, somewhat below the 2.8-percent rate for all manufacturing.[1] (See table 1.) Output increased at an average annual rate of 4.5 percent while employee hours advanced at a rate of 2.1 percent. For the most recent period, 1973–80, productivity has risen at a faster annual rate—averaging 3.0 percent. Improved preparatory and spinning equipment have contributed to these gains.

Growth varied over the period of study. From 1958 to 1965, productivity increased every year, rising at an average annual rate of 5.2 percent. The largest jump occurred in 1961 with a rise of 9.3 percent. The 5.2-percent average gain in productivity reflected an average annual growth of 6.7 percent in output and 1.5 percent in employee hours. Since 1965, productivity gains have slowed considerably. During 1965–73, output per employee hour grew at an average annual rate of only 1.2 percent. Output increased at a 4.6-percent rate—just slightly faster than that of 3.4 percent for employee hours. Productivity movements displayed much year-to-year fluctuation during this time. There were increases in only 5 of 9 years, with the largest—7.1 percent—occurring in 1971.

In contrast to productivity movements for most industries, the growth in this industry accelerated during 1973–80, rising at an average annual rate of 3.0 percent. Output grew at a rate of 2.6 percent, while employee hours declined at a rate of 0.4 percent. Recessionary conditions in the economy in 1974 and 1975 had a strong impact on the trends in output and employee hours. In 1974, the yarn industry began sharp reductions in employee hours, as output fell 3.5 percent. The more than proportional drop in employee hours of 7.9 percent led to a 4.8-percent rise in productivity. In 1975, output posted a further decline of 4.2 percent. In the face of this continuing deterioration in output, employee hours experienced their largest single-year decline in the entire 1958–80 period, 15.7 percent. The resulting productivity increase, 13.6 percent, was the largest of the two-decade period.

Employment and plant size

Total employment in the spun yarn industry increased by more than 28 percent between 1958 and 1980, rising at an average annual rate of 2.1 percent. There were 67,800 employees in 1958, but by 1980 the total had risen to 86,900. However, the increase in employment was not steady; cyclical patterns were evident throughout the period, which were related to trends in the overall economy.

The establishments which produce yarn vary in size but, generally, are rather large. According to the 1977 Census of Manufactures, nearly 40 percent of all establishments employ 100 to 249 employees and these account for more than 30 percent of industry value of

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Table 1. Productivity and related indexes for nonwool yarn mills, 1958–80

[1977=100]

Year	Output per employee hour	Output	Employee hours	Employees
1958	59.5	39.4	66.2	72.9
1959	62.3	44.8	71.9	72.9
1960	65.3	42.5	65.1	68.6
1961	71.4	45.1	63.2	65.6
1962	74.7	48.7	65.2	66.3
1963	76.3	50.3	65.9	66.3
1964	80.6	57.4	71.2	69.1
1965	84.6	66.5	78.6	73.8
1966	81.8	66.7	81.5	78.0
1967	77.5	61.7	79.6	80.1
1968	80.2	68.2	85.0	83.3
1969	84.5	74.4	88.0	89.3
1970	84.3	70.9	84.1	86.3
1971	90.3	82.0	90.8	89.2
1972	91.0	91.2	100.2	96.4
1973	85.0	88.9	104.6	102.7
1974	89.1	85.8	96.3	101.2
1975	101.2	82.2	81.2	87.7
1976	93.5	89.7	95.9	97.7
1977	100.0	100.0	100.0	100.0
1978	104.2	103.8	99.6	100.3
1979	103.9	99.0	95.3	95.8
1980	106.1	97.5	91.9	93.4
Average annual rates of change (in percent)				
1958–80	2.3	4.5	2.1	2.1
1975–80	1.7	3.4	1.7	0.7

shipments. Of the 456 establishments in the industry, almost 20 percent employ 250 to 499 employees and also account for more than 30 percent of total value of shipments. Only about 7 percent of all establishments employ 500 to 999 employees but these produce more than 20 percent of industry value of shipments.

Production workers have always represented a high proportion of total industry employment and that proportion has changed very little over time. In 1958, they accounted for slightly more than 94 percent of total employment and in 1980 their share was still about 92 percent. The proportion of female employees has increased in recent years, rising from approximately 44 percent of the work force in 1972 to 46 percent in 1980.

Average hourly earnings in the spun yarn industry have remained well below those of all manufacturing. In 1972, the first year for which such data are available, average hourly earnings were $2.53, significantly less than the $3.82 for all manufacturing. By 1980, average hourly earnings in the industry had risen about 89 percent to $4.78. However, this was still well below the average for all manufacturing, which was up to $7.27.

Diverse industry markets

Spun yarn is used for the manufacture of the great majority of textile products; household items which contain yarn include carpets and rugs, bedspreads, draperies, and towels. Its demand can be influenced by population changes, housing starts, changes in lifestyle or consumer tastes, and general economic conditions.

Nonwool yarn is purchased by many different manufacturers. Broad woven fabric mills are major users of spun yarn. These mills produce goods made from cotton, synthetic fibers, and silk, such as sheets, pillowcases, draperies, and towels. The firms which use synthetic fibers and silk are the largest purchasers of spun yarn. From 1963 to 1977, purchases by nonwool spinning mills increased nearly 90 percent, but those by broad woven cotton mills changed very little.[2]

Mills which produce knit fabric also account for a large proportion of total spun yarn purchases. These mills knit tubular or flat fabric and dye or finish knit fabric; their output increased rapidly from 1963 forward. This increase in output translated into rising yarn purchases by these mills. It is estimated that between 1963 and 1967, purchases of spun yarn by both circular and warp knit fabric mills increased by approximately 136 percent.

Other types of knitting mills also use spun yarn, including knit outerwear and underwear mills and hosiery mills. The first type manufactures products such as suits, slacks, shirts, neckties, and skirts. Although complete information is not available for all years, estimates indicate that purchases of spun yarn by knit outerwear mills decreased during the 1963–77 period.

Exports have historically accounted for a negligible portion of the total market. In 1979 and 1980, although exports increased rapidly, they only accounted for approximately 2 percent of yarn shipments. Imports have had little impact on the domestic market, making up less than 1 percent of apparent consumption in recent years.[3]

Advances in technology

The production of spun yarn involves a number of different operations. Improvements in technology have taken place at different stages of the production process and have contributed to the industry's overall growth. Much of the advance has resulted from gradual improvements in the equipment over time.

The raw material arrives at the mill as bales. The adoption of automatic bale opening and blending equipment, which eliminates the need for manual performance of this operation, has led to greater efficiency in this initial stage of the production process.

Likewise, improvements have occurred in the carding operation. In it, the fibers of the raw material are made parallel to each other and most of the foreign matter is removed. The fibers emerge in a form known as sliver. Formerly, the yarn entered a picker which formed it into a roll before being fed into the carding machine. However, the introduction of the automatic chute feed which permits the blended fibers to be fed directly into

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the carding machine, has eliminated the need for a picker. The carding machinery itself has increased in speed, further contributing to productivity gains.

The drawing and roving operations follow the carding process. The drawing operation makes the slivers more uniform. In the roving process, a twist is imparted to the sliver by the roving frame. This results in greater strength. The product that emerges is known as roving and is wound onto bobbins which are taken up when full. The adoption of larger bobbins has reduced the amount of tending necessary because they do not have to be removed as often. Improved roving equipment has been introduced which is faster and eliminates the need to remove the flyers (which insert twist into the fibers) for doffing (removal of the bobbins).

After the roving operation, the roving bobbin proceeds to the spinning operation. The spinning drafts (draws out) the fibers to size the yarn and puts the desired twist into it, providing necessary strength. Yarn is spun onto bobbins; the use of larger ones on spinning machines has reduced the frequency with which bobbins have to be removed. The introduction of automatic doffing equipment—equipment which removes the full bobbins and replaces them with empty ones—has also improved productivity. Increased operating speed of the spinning equipment itself has also contributed to productivity gains.

After spinning, the yarn is taken to the winding department. Here, winding machines remove the yarn from the spinning bobbins and wind it onto cones for direct customer shipment or onto tubes for dyeing. Automation in winding equipment has taken place and has increased productivity growth immensely.[4]

A number of plants have introduced open-end spinning, which has also aided productivity. This combines into one process the three separate operations of roving, spinning, and winding, thus eliminating the need for a separate roving and winding operation. Open-end spinning can wind the yarn onto a package rather than a spinning bobbin; thus, a separate winding operation to transfer the yarn from the spinning bobbin to a cone is no longer needed.[5]

Capital spending

Rises in labor productivity are frequently linked to increases in capital formation. Data available through 1979 indicate that, over 1958–79 as a whole, current-dollar new capital expenditures rose at an average annual rate of 9.4 percent. However, the advances were not uniform throughout the period, and the most rapid ones took place in the earlier years. From 1958 to 1966, new capital expenditures increased at a 22.1-percent rate. This acceleration in capital spending coincided with rapid productivity growth. During 1958–66, the rate of increase in output per employee hour was 4.6 percent. Both productivity and capital expenditures posted increases in all but one year of the 1958–66 subperiod.

The tremendous growth in capital expenditures during this time caused the ratio of capital expenditures per employee to go up far more rapidly than for all manufacturing. In 1958, capital spending per employee was only $229 in the spun yarn industry, compared with $619 for all manufacturing. However, by 1966, capital spending per employee in the industry had risen to $1,368, compared with $1,112 for all manufacturing.

From 1966–79, the trends in both capital expenditures and productivity were quite different from the preceding years. The rate of increase in capital expenditures declined to 4.9 percent. There were even substantial decreases in a number of years. Productivity growth likewise experienced a slowdown, dropping to an average annual rate of increase of 2.2 percent. As in the case of capital expenditures, there were declines in some years. The decline in the growth rate of capital expenditures caused the rate of increase in the ratio of capital expenditures per employee to fall behind that of all manufacturing. From 1966–79, capital spending per employee in the spun yarn industry advanced at an average annual rate of only 3.0 percent, compared with a rate of 9.2 percent for all manufacturing. Consequently, capital spending per employee was only $1,607 in 1979, compared with $3,118 for all manufacturing.

PRODUCTIVITY SHOULD CONTINUE to increase as improvements in production equipment take place and as more manufacturers take advantage of these. Some of the newer equipment, which embodies more advanced technologies than past models, is capable of producing better quality yarn with fewer imperfections and weak spots. This top quality is increasingly demanded by customers as they adopt higher speed weaving and knitting machinery.[6] This is accelerating the adoption of more modern production equipment by nonwool yarn mills.

Some industry officials expect labor market conditions to provide added stimulus for use of improved production equipment.[7] Relocation of the manufacturing operations of many industries into major textile producing areas exerts additional pressure on existing labor and wages. This, in turn, is impelling more yarn manufacturers to utilize the equipment and techniques which provide the greatest levels of output per employee hour.

Open-end spinning will continue to contribute to productivity gains as it becomes more widely adopted. This form of spinning has a particularly favorable effect on production efficiency because, as noted earlier, it combines the separate operations of roving, spinning, and winding into a single process.

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[1] The nonwool yarn mill industry consists of establishments primarily engaged in spinning yarn wholly or chiefly by weight of cotton, synthetic fibers, or silk. It is designated as industry 2281 in the 1972 Standard Industrial Classification (SIC) Manual. All average annual rates of change are based on the linear least squares trend of the logarithms of the index numbers. Extension of the indexes will appear in the annual BLS Bulletin, *Productivity Measures for Selected Industries.*

[2] The discussion of yarn purchases from nonwool yarn mills by the consuming industries is based on constant-dollar estimates.

[3] *U.S. Industrial Outlook* (U.S. Department of Commerce, 1981), p. 402.

[4] See McAllister Isaacs III, "Winding a 138 Percent Boost in Operator Pounds," *Textile World*, February 1980, pp. 79–82.

[5] See Brenda V. Lloyd, "Meeting the Challenges of Modernization," *Textile Industries*, September 1979, pp. 114–17. Also, see McAllister Isaacs III, "Avondale Open-End Cuts Labor, Ups Output," *Textile World*, May 1980, pp. 63–66.

[6] W. Bud Newcomb, "U.S. Sales-Yarn Firms Are Poised For Future Growth," *Textile World*, September 1980, p. 203.

[7] See Douglas A. Bowen, "Linn-Corriher: Yarn Making Pioneer," *Textile Industries*, March 1980, p. 50. Also, see Joseph L. Lanier Jr., "Plants and Equipment," *America's Textiles*, June 1976, p. 21.

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The office furniture industry: patterns in productivity

Product proliferation and short production runs limited the use of laborsaving equipment in office furniture establishments; as a result, productivity grew only moderately during 1958–80

J. EDWIN HENNEBERGER

Productivity growth (as measured by output per employee hour) in the office furniture industry[1] has been low, in large part because of relatively short production runs engendered by product proliferation. Between 1958 and 1980, the industry posted an average annual productivity gain of 1.8 percent, substantially below the 2.8-percent rate for all manufacturing industries. The gain resulted from growth in output of 5.5 percent, annually, and employee hours of 3.6 percent.

In many industries, declines or small gains in output are associated with reduced or even negative growth in productivity. This seems to be true of the office furniture industry as a whole. (See table 1.) Thus, in the 9 years in which output either declined or grew at a less than average rate, productivity either fell or grew at a less than average rate in 5 of these years.

The trend in productivity for the overall office furniture industry must be viewed in light of the underlying trend movements of the two component industries—wood office furniture and metal office furniture. Metal furniture is the dominant industry in the office furniture group, employing about two-thirds of the 53,000 workers and accounting for roughly the same percent of shipments. Although both industries exhibited nearly the same growth in productivity between 1958 and 1980 (1.7 percent for wood furniture and 1.8 percent for metal furniture), the growth in output and employee hours was more diverse, with both output and hours growing at much higher rates in the wood component (7.2 percent and 5.5 percent) than in metal (4.6 percent and 2.8 percent).

The metal office furniture industry, which experienced five output downturns between 1958 and 1980, was, nevertheless, able to maintain productivity growth in all but 2 of these years. This suggests that the industry's work force is flexible and can be rapidly reduced if industry sales are declining. However, the wood office furniture industry was never able to maintain positive productivity during the six declines in output from 1958 to 1980. The more highly skilled work force, utilizing craftworkers, in the wood segment may be more difficult to periodically layoff and rehire.

Productivity trends have varied

The industry's long-term productivity growth can be divided into three periods (table 1). From 1958 to 1966, productivity grew at a rate of 3.6 percent annually. Slowing dramatically, productivity growth advanced by only 0.1 percent per year during the middle time span —1966 to 1975. However, from 1975 to 1980, the rate of advance increased to 5.1 percent per year.

Recession-induced falloffs were particularly acute from 1966 to 1975. During the 1970 recession, industry output dropped 17 percent while employee hours were reduced by 6.6 percent. Consequently, productivity in 1970 fell by more than 11 percent. During the 1974–75 recession, output declined 5.3 percent in 1974 and 17.7 percent in 1975 while productivity posted its largest falloff in 1974 (−8.3 percent). More recently, productivity exhibited positive growth during the short reces-

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Table 1. Productivity and related indexes for the office furniture industry, 1958–80

[1977 = 100]

Year	Output per employee hour	Output	All employee hours	Employees
1958	64.0	33.1	51.7	51.8
1959	69.8	37.5	53.7	52.9
1960	70.4	39.4	56.0	54.7
1961	72.5	38.4	53.0	51.8
1962	74.4	42.1	56.6	55.8
1963	75.9	45.6	60.1	58.7
1964	82.1	50.8	61.9	60.0
1965	84.2	57.5	68.3	64.9
1966	86.7	67.9	78.3	74.7
1967	86.5	69.7	80.6	78.2
1968	85.2	70.9	83.2	78.7
1969	88.0	81.4	92.5	88.9
1970	78.2	67.6	86.4	82.7
1971	83.9	64.8	77.2	74.9
1972	91.8	82.7	90.1	87.3
1973	90.6	87.5	96.6	94.4
1974	83.1	82.9	99.8	98.9
1975	85.5	68.2	79.8	81.8
1976	89.7	75.8	84.5	85.6
1977	100.0	100.0	100.0	100.0
1978	100.1	108.1	108.0	107.8
1979	107.3	121.1	112.9	110.9
1980	108.9	125.9	115.6	118.4
	Average annual rates of change			
1958–80	1.8	5.5	3.6	3.8
1958–66	3.6	8.4	4.6	4.1
1966–75	0.1	1.4	1.4	2.0
1975–80	5.1	13.9	8.3	8.0

sion in 1980. However, this gain in productivity (1.5 percent) was somewhat less than the industry's long-term growth (1.8 percent per year).

Among the component industries, the same midterm pattern of productivity slowdown is evident. (See table 2.) From 1958 to 1966, productivity advanced in both industries at about 3.6 percent per year. But from 1966 to 1975, productivity fell at an annual rate of 1.1 percent in the wood component while advancing by only 0.5 percent per year in the metal furniture industry. Rebounding from the recession-marked middle period, productivity advanced sharply from 1975 to 1980 in the wood and metal industries—7.2 and 3.8 percent, respectively. Output in this recovery period was up sharply in both industries, paced by the nearly 22-percent average annual growth in wood furniture. Lagging somewhat behind wood furniture, the output of metal furniture increased by about 10 percent per year during this later period, as market share was lost to the more natural look and feel of wood.

Office furniture demand growing

Between 1958 and 1980, output of the office furniture industry grew at an average annual rate of 5.5 percent per year, substantially above the 3.8-percent average rate for all manufacturing industries. A number of factors have shaped the demand for office furniture and the industry's output growth. Some of these factors have included the amount of available office space, growth of the white-collar work force, replacement demand, and the introduction of new products.

The most important factor influencing the long-term growth of office furniture undoubtedly has been the growth of the white-collar or office work force. Between 1958 and 1980, white-collar workers have grown from about 27 to nearly 53 million. Currently, officeworkers account for slightly more than one-half of the total employed work force.[2] This translates into a 2.9-percent average annual increase. Available office space also is a determinant of office furniture demand. The amount of public and private detached office space doubled between 1958 and 1980.[3]

As the stock of existing office furniture grows, the demand for replacement of wornout or obsolete equipment grows also. The data suggest that in recent years roughly one-third of office furniture production has been consumed by the replacement market.[4]

The introduction of new products also stimulates increased demand for office furniture. In the past, office furniture usually consisted of desks, chairs, tables, and storage equipment, sold as individual pieces. Now, modular or systems furniture is sold as complete integrated packages that include movable partitions, storage components, and service modules. Advantages claimed

Table 2. Productivity indexes for the office furniture and two component, 1958–80

[1977=100]

Year	All office furniture	Wood furniture	Metal furniture
1958	64.0	67.1	64.5
1959	69.8	69.5	71.6
1960	70.4	68.0	72.7
1961	72.5	70.5	74.7
1962	74.4	69.9	77.9
1963	75.9	80.4	75.9
1964	82.1	84.5	82.9
1965	84.2	82.8	86.3
1966	86.7	85.9	88.3
1967	86.5	88.1	87.6
1968	85.2	87.7	86.2
1969	88.0	91.9	88.5
1970	78.2	83.9	78.0
1971	83.9	81.2	86.4
1972	91.8	84.5	96.7
1973	90.6	78.5	97.9
1974	83.1	83.0	84.5
1975	85.5	80.5	88.9
1976	89.7	81.9	94.8
1977	100.0	100.0	100.0
1978	100.1	100.7	99.9
1979	107.3	110.7	104.8
1980	108.9	109.2	108.6
	Average annual rates of change		
1958–80	1.8	1.7	1.8
1958–66	3.6	3.5	3.6
1966–75	0.1	−1.1	0.5
1975–80	5.1	7.2	3.8

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for systems furniture include design flexibility, more efficient use of floor space, low rearrangement costs, and built-in electrical outlets. In recent years, systems furniture has outpaced the growth of conventional office furniture. Currently, systems furniture accounts for about 20 percent of the total office furniture market. Computers and word processors, which require support furnishings, have also resulted in increased demand for office furniture.

Industry employment more than doubles

The number of employees in the office furniture industry increased from 23,000 in 1958 to about 53,000 in 1980. Sustained expansion of the work force during the 1960's accounted for much of this growth.

While the overall employment growth for the industry was 3.8 percent per year from 1958 to 1980, employment trends varied among the subindustries. The work force in the wood office furniture industry expanded at an average of 6.0 percent per year. The metal furniture industry grew at less than half of that—2.8 percent per year.

Compared with other manufacturing industries, office furniture production is relatively labor intensive. About 10 percent more production worker hours are needed to generate $1 of added value in office furniture than in all manufacturing. Among the component industries, wood office furniture is the most labor intensive.

Production workers accounted for 79 percent of total industry employment in 1980, down slightly from the 81 percent reported in 1958. About 25 percent of the industry's workers in 1980 were women, slightly less than the 31 percent level for all manufacturing. Average hourly earnings of production workers—$5.92 in 1980—were somewhat below that of the all manufacturing rate of $7.27. Over the long term, employee turnover has been slightly below that of the all manufacturing rate.

Industry establishment size increasing

Although office furniture production is geographically dispersed throughout the United States, there is a large concentration of firms in Ohio, Indiana, Illinois, Michigan, and Wisconsin, with many plants clustered in and around Grand Rapids, Mich. Until World War II, the Grand Rapids area had been a major center for household furniture. After the war, the household furniture industry dispersed, and commercial and office furniture manufacturers moved in to fill the void.

From 1958 to 1977, the number of establishments in the industry has been growing. In the wood segment, the number of establishments more than doubled, while in metal furniture, the number increased by only 25 percent. For the industry as a whole, average employment size per establishment increased by about 12 percent. During the same period, companies primarily manufacturing office furniture increased from 289 in 1958 to 486 in 1977—most of this growth occurring in the wood furniture segment. At the same time, the proportion of industry shipments accounted for by the four largest companies in each industry increased modestly.

Between 1975 and 1980, the average annual growth in capital expenditures per employee was lower for the office furniture industry than for all manufacturing. For example, from 1958 to 1975, capital expenditures per employee grew at an annual rate of 6.3 percent in office furniture, while the all manufacturing rate over the same time period was 7.5 percent. Productivity growth over this period was also lower in the office furniture industry than in all manufacturing. From 1975 to 1980, however, capital expenditures per employee accelerated to 29.6 percent per year, compared with a rate of 11.1 percent for all manufacturing. Productivity from 1975 to 1980 increased sharply also, growing at a rate of 5.1 percent. The level of expenditures per employee, however, has been substantially less than all manufacturing. In 1980, the office furniture industry expended roughly $2,900 per employee for new capital equipment while the all manufacturing average was almost $3,700.

Manufacturing innovations limited

Typically, production in the office furniture industry takes place at mechanized work stations with workpiece transfer accomplished by conveyor line, forklift truck, or handcart. The wood furniture industry employs general purpose woodworking machinery such as saws, planers, glue presses, and sanders. Basic operations in the metal furniture industry include metal cutting, stamping, welding, and tubeforming. With minor differences, both industries have common operations such as painting and upholstering. Obviously, many of the processes used for manufacturing wood furniture bear little resemblance to those used for metal furniture. However, even within the component industries, variations in equipment and processes are evident. This is particularly true of wood furniture. Some of the finer grades are produced almost entirely by hand, while the less expensive grades are produced in assembly line fashion.

Product proliferation is a problem within the office furniture industry, and this has hindered the introduction of special purpose and highly efficient machinery and equipment. While the household furniture industry finds it relatively easy to drop product lines and styles, office furniture companies must maintain the capacity to produce old as well as new product lines. This problem is particularly acute in the more expensive wood office furniture lines. Reorders of wood furniture must match style as well as wood grain pattern and color (which may not be the same as when the pieces were new).

Therefore, the potential number of product types, styles, and colors, coupled with the bulkiness of furni-

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ture, discourage factories from accumulating large inventories of finished goods. Most office furniture, perhaps as much as 90 percent, is for order rather than inventory. Office furniture dealers do not stock large inventories either; rather, an accumulation of customer orders is periodically sent to the factory. This results in short production runs of individual items.

This diminished ability to control production runs may be one of the reasons productivity growth in the office furniture industry has been less than that of the household furniture industry.[5] The office furniture industry must remain even more flexible in terms of production capabilities than household furniture manufacturers, many of whom are also troubled by short, inefficient production runs and difficulty in incorporating highly specialized and efficient equipment. Nevertheless, some notable advances in the technology of manufacturing office furniture have been introduced.

In the wood office furniture industry, one of the most pronounced trends in innovation has been increased use of particleboard. While the primary impetus for the expanded usage of particleboard has been its lower cost in relation to the cost of solid lumber, the industry has focused considerable attention on new technologies to handle the material. A wide variety of surface laminates and films and application techniques have eliminated several time-consuming production and assembly operations. Groove-folding, a technique whereby V-shaped grooves are cut in the particleboard substrate, but not through the flexible surface material, produces seamless furniture edges which are held in place by the continuous outer wrap.[6]

Although somewhat hampered by increased petrochemical prices in recent years, the use of plastic materials has simplified construction and added strength to furniture components, and can also produce mar-resistant surfaces. Reconstituted wood veneer, another advance in materials, has uniform thickness, grain, and quality and can be evenly stained. Its use eliminates the need for the labor intensive procedure of manually grading, selecting, and removing defects from natural veneers.

In addition to new materials, notable advances have occurred in woodworking machinery. Abrasive planing, introduced in the early 1960's, combines heavy stock removal with direct dimensioning at the sanding machine.[7] Machines which glue and trim veneer strips to the edges of particleboard can eliminate the complicated set of clamps and pressure bands which formerly had to be locked in place until the glue dried.

In the metal office furniture industry, machines have recently been installed that automatically position and cut shapes into the large flat metal blanks that later will be fashioned into desks, file cabinets, and so forth. This equipment is more efficient because it does not require moving the workpiece to a separate machine for each cut. Also, setup time is considerably reduced.

Savings in the time needed to produce tubular shapes have been accomplished by new tubeforming and cutting equipment. Tubemaking, which starts from flat coiled steel, has been speeded up by the use of automatic welders which join the ends of the coils so that the tubeforming equipment need not be shut down while coils are being changed.

Metallic inert gas (MIG) welding has largely supplanted most other forms of welding. Its advantage is that the parts being joined do not have to be as thoroughly cleaned as with brazing. Although robot welders are not common, automatic welding is. Once travel and angle of the welding arm have been adjusted, a worker is required only to load and unload workpieces onto and from the equipment.

Although not designed specifically for the metal office furniture industry, automated parts inventory storage and retrieval systems are being used by several plants in the industry. Operating under the control of a computer which "explodes" or breaks down orders for the required number of finished pieces of furniture into the necessary parts demand, robot crawlers and unmanned forklift trucks retrieve and deliver the parts to various pickup stations where they are transferred to the assembly line in the correct sequence for manufacture.

Upholstering, an operation which is similar in both wood and metal office furniture, is a particularly labor intensive operation and requires a skilled work force. Although still used in many plants, manual pattern layout and fabric cutting have in some cases been phased out, superseded by diecutting of fabric. Computer-controlled cutting equipment, which combines high speed with accuracy and eliminates manual pattern layout, is also available.[8] Steam tables, installed at upholsterers' work stations, expand the cut fabric workpiece. Once removed from the steam and stapled around the foam rubber cushion, the fabric shrinks back to its normal size and becomes taut. Airpowered plunger tables, used to compress the fabric-covered foam shape, have made button insertion and tiedown operations easier.

Electrostatic finishing, used widely by the metal furniture industry, can be used successfully on wooden furniture,[9] resulting in increased labor productivity in the finishing area and a substantial reduction in material and maintenance costs. Automatic electrostatic spray lines allow closer spacing of pieces to be painted and, thus, greater efficiency. With these automatic lines, color changeover is automatic and can be done in 30 seconds rather than the 2 minutes previously required on the nonautomatic electrostatic lines. Electrodeposition lines, which are powdered coatings in a medium of either air or water, are particularly efficient with respect to labor, materials, and solvent emissions.

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Likewise, both the metal and wood office furniture industries have shared the advances made in portable, handheld power fastening tools, resulting in added worker efficiency through more power, greater capacity, and less weight and maintenance. Productivity has also been enhanced by improved workflow layout, computerized recordkeeping, and new materials such as quick-setting glues and improved finishes.

Recent trends may continue

If continued, the industry's capital spending surge of the last few years may provide the plant and equipment necessary to maintain the recent above average growth in productivity. However, the current economic downturn may have a negative effect on demand and productivity.

Although the full consequences of the current economic downturn cannot be foreseen, it is worth noting that previous recessions have had only limited effects on the growth of the white-collar work force, one of the key factors in the output growth of the office furniture industry. In fact, even though there have been four recessions since 1958, the total white-collar work force has never declined. With the forecasted continued expansion in the white-collar work force,[10] demand for the industry's products should continue to increase and may, therefore, present the industry with opportunities to expand productivity. Also, the industry's output should be further bolstered if the growth of systems furniture continues.

While the "paperless office" is not as yet a reality,[11] over the long term, the increasing sophistication of electronic office equipment may result in officeworkers becoming more productive. This, in turn, can influence output of the office furniture industry by dampening growth in the white-collar work force and affecting demand and productivity in the office furniture industry.

[1] The office furniture industry is classified as SIC 252 in the 1972 *Standard Industrial Classification Manual* and its 1977 supplement, issued by the U.S. Office of Management and Budget. The subindustries within the office furniture group include establishments that are primarily engaged in manufacturing furniture commonly used in offices—wood (SIC 2521) and metal (SIC 2522).

[2] *Employment and Training Report of the President*, 1981 Report (The White House, 1981), pp. 148–49; see also table 3, p. 73, of the April 1982 issue of the *Monthly Labor Review*.

[3] See P. W. Daniels, ed., *Spatial Patterns of Office Growth and Location* (New York, John Wiley & Sons, Inc., 1979), pp. 67–69.

[4] "Equipment Purchases Planned by Readers in 1980," *The Office*, January 1980, p. 26.

[5] See J. Edwin Henneberger, "Productivity Growth Below Average in the Household Furniture Industry," *Monthly Labor Review*, November 1978, pp. 23–29.

[6] Darrell Ward, "Groove Folding for Contract and Contemporary," *Woodworking and Furniture Digest*, June 1981, pp. 42–45.

[7] ——, "Abrasive Planing Challenges Your Knife Cutting Techniques," *Hitchcock's Wood Working Digest*, November 1963, pp. 29–32.

[8] Robert Michael, "New Techniques of Computerized Fabric Cutting," *Furniture Methods and Materials*, June 1971, pp. 12–15.

[9] Richard D. Rea, "Electrostatic Disks Win," *Woodworking and Furniture Digest*, April 1982, pp. 22–25.

[10] *Economic Projections to 1990*, Bulletin 2121 (Bureau of Labor Statistics, 1982), pp. 34–47.

[11] See Paul Lieber, "Office Automation: The Job Threat that Never Happened," *The Office*, May 1980, p. 158.

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Productivity in the pump and compressor industry

During 1958–80, the industry experienced long-term advances, reflecting improvements in metalworking machinery and computer aid; but since 1965, productivity has decelerated, being especially slow from 1973 forward

HORST BRAND AND CLYDE HUFFSTUTLER

Output per employee hour in pump and compressor manufacturing rose at an average annual rate of 2.1 percent between 1958 and 1980—compared with a rate of 2.6 percent for manufacturing as a whole.[1] Output increased 4.7 percent a year, employee hours 2.6 percent. Among the sources of the industry's long-term productivity advance were improvements in metalworking machinery, which lies at the core of the production processes for pumps and compressors, and computer technologies, which were increasingly applied to engineering design.

The labor productivity trend for the industry was marked by strong advances during the early part of the period (from 1958 to 1965), followed by deceleration during 1965–73, and a further slowing thereafter. As the tabulation shows, using average annual rates of change in percent, the trend pattern paralleled manufacturing:

	Pumps and compressors	*Manufacturing*
1958–80	2.1	2.6
1958–65	3.4	2.7
1965–73	2.1	2.4
1973–80	1.0	1.8

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By 1980, the level of labor productivity in the industry had risen 55 percent from 1958, as against 78 percent for all manufacturing.

The long-term productivity trend, in addition to evidencing divergent medium-term movements, was punctuated by sharp year-to-year swings. These swings were generally related to the business cycle, although they show no uniform pattern. Thus, labor productivity fell steeply in 1960 (3.2 percent), 1975 (5.6 percent), and 1980 (2.6 percent). In these years, output either grew more slowly than employee hours (1960), or fell more rapidly (1975), or fell while hours rose (1980). Yet, in 1961, 1967, and 1971, years when the economy slowed, significant increases in productivity occurred (3.9 percent, 1.7 percent, and 1.5 percent)—which, however, stemmed from drops in employee hours exceeding drops in output.

Years of recovery or boom in which productivity soared to more than twice its long-term rate, displayed a more uniform pattern of change in output and employee hours. In 1959 and 1976, gains in productivity were linked with large output increases but slight employee hour declines.

Separate data for pumps and pumping equipment, and for air and gas compressors, are available only from 1972 forward. Average annual rates of change in labor productivity for the two separate industries compare as follows for the 1972–80 span:

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	Percent
Pumps and compressors	1.2
Pumps and pumping equipment	1.2
Air and gas compressors	1.1
All manufacturing	1.9

Reflecting contrasting trends in output and employee hours, labor productivity movements in the pump and pumping equipment segment were considerably less volatile than in compressor manufacturing. The former attained a productivity level in 1979 that exceeded 1973 by 7 percent (both years registered cyclical peaks); the latter failed to reattain its 1973 high.

Output increases

Pumps and compressors are used throughout manufacturing and many nonmanufacturing industries, as well as agriculture. Pumps are the second most common machine in use after the electric motor.[2] Compressors generate compressed air, which may be regarded as a form of energy ranking in breadth of use only below electricity, gas, and water, in addition to being indispensable in the transportation of gas.[3]

Between 1958 and 1980, output of pumps and compressors rose 175 percent, or at an average annual rate of 4.7 percent. Manufacturing output grew at a rate of 3.8 percent over the period. Like the long-term trend in the industry's labor productivity, the long-term trend in output rose less after 1965 than earlier, as the following tabulation indicates by showing average annual rates of change in percent:

	Pumps and compressors	*Manufacturing*
1958–80	4.7	3.8
1958–65	6.5	5.9
1965–73	2.5	3.0
1973–80	4.2	2.5

Output of pumps and compressors reached a peak index level of 115 (1977=100) in 1979, from which it receded slightly in 1980. The dip was caused by a decline in compressor manufacturing, which had climbed 51 percent between 1973 and 1979. Pump and pumping equipment output had risen 22 percent between those 2 years of cyclical highs.

Of the total output of pumps and compressors, the former accounted for about two-thirds, according to the *1977 Census of Manufactures*, the latter for the remaining one-third. Industrial pumps represented more than half of the output of pumps and pumping equipment (other than accessories). Hydraulic fluid power pumps, oil well and oilfield pumps, and other pumps and equipment installed in appliances, fire engines, and structures, made up the remaining output. Parts and attachments constituted close to one-quarter of pump manufacturing output in 1977. Given the often difficult climatic and environmental conditions in which pumps must operate, and the abrasiveness of fluids often transferred by them, speedy replacement of worn and damaged parts constitutes a vital function of the manufacturer, and is the reason for the high proportion of shipments of parts and attachments.

Air compressors accounted for well over one-quarter of the shipments of compressor manufacturers, according to the 1977 census, gas compressors for just under one-tenth. They consisted preponderantly of the stationary type. Portable compressors, which are relatively small machines, made up one-fifth of total air and gas compressor shipments. Industrial spraying equipment also added one-fifth to compressor manufacturers' shipments. Compressors, like pumps, are frequently exposed to rough operating and environmental conditions, hence a comparatively high proportion of shipments (20 percent) represented parts and attachments in 1977.

Factors underlying output growth

In general, growth in the output of pumps and compressors was related to expansion in industrial and public utility demand, particularly during the boom years of the early and mid-1960's; gains in residential and associated public works construction, such as sewage and waterworks, during the 1960's and 1970's; and intensified needs of energy-related extractive and pipeline industries, especially during the 1970's. Foreign trade, too, played an important role in sustaining output: about one-fifth of pump and compressor production was exported between 1972 and 1978.

Expansion in the productive activities of a wide array of users lay at the base of output growth of pumps and compressors. No precise statistical link can be established between the former and the latter. However, movements in the plant and equipment expenditures, adjusted for price changes, by major pump and compressor users are indicative, as are put-in-place data for construction.

Among large-scale users of pumps and compressors was the chemical industry, which accounts for about one-tenth of total pump and compressor output.[4] Chemicals nearly doubled plant and equipment outlays (adjusted for price changes) in the early 1960's, then reduced them. After 1973, however, outlays were once again raised, so that in 1979 they stood nearly twice above the 1973 level. The industry has increasingly used pumps made of fiberglas, plastics, and stainless steel to transfer salt solutions, acid, and chlorine.[5]

Steel mills and blast furnaces, whose capital spending patterns compared roughly with that of the chemical industry over the review period, purchase about 7 percent of pump and compressor output. They use a variety of industrial and hydraulic pumps as well as compressors

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to move sources of energy such as liquid fuels, as well as water to absorb waste energy. Installation of multistage pumps to achieve higher pressure has, in part, been prompted by the shift from open-hearth to basic-oxygen and electric-arc steelmaking processes. The partial replacement of slabbing mills by continuous casting has required more water, hence a larger number of and more powerful centrifugal pumps.[6]

More than 18 percent of pumps and compressors are bought by energy-related extracting, processing, and distributing industries. Thus, growth in extractive activities spurred the demand for industrial as well as oil well and oilfield pumps. Between 1960 and 1970, the number of crude oil and gas wells drilled dropped sharply (by nearly two-fifths), as did footage drilled (by 27 percent). After 1970, the decline was reversed; in 1978, the two indicators ran 72 percent and 68 percent above 1971 levels. Concomitantly, output of oil well and oilfield pumps, which had risen at an average annual rate of less than 4 percent between 1958 and 1973, soared to a rate of more than 10 percent between 1973 and 1980. Oil extraction also requires reciprocal pumps for mud circulation; submersible centrifugal units to lift the crude oil; and centrifugal pumps for waterflooding (to prevent subsidence and maintain pressure).[7]

Compressors are required in oil drilling and oilfield maintenance operations, and particularly in secondary recovery efforts. The continued expansion of natural gas pipelines (whose mileage increased 9 percent between 1973 and 1978) spelled the installation of additional large compressors for gas transmission; and increases in new wells—more than twofold between 1973 and 1978—required numerous smaller compressors for gas gathering, as did the prohibition of flaring of waste gas (which now must be stored in tanks). Also, steep increases in capital expenditures of the coal mining industry—162 percent between 1958 and 1972 (after adjustment for price changes), and 169 percent between 1973 and 1977—indicate expansion in this industry's demand for compressors.

Expansion of petroleum pipeline capacity also raised the demand for pumps, particularly of the high-horsepower centrifugal kind, and for stationary compressors. While the network of petroleum pipelines operated by petroleum pipeline companies increased 16 percent between 1960 and 1970, and contracted somewhat thereafter, total oil transported rose 81 percent during the 1960's, and 48 percent in the 1970's.[8] At the same time, the average diameter of pipes was enlarged by one-third, roughly doubling capacity.[9] This required significant increases in the size and capacity of pumping equipment and compressors.

Expanding electrical generating capacity spurred the output growth especially of centrifugal pumps. These are used as boiler-feed pumps, as well as in many other operations requiring the circulation and condensation of steam and water. While the total number of electrical generating stations did not advance very much over the review period, the proportion of stations generating 500,000 kilowatts or more rose from under 3 percent in 1960 to 12 percent in 1979. Nuclear and gas-turbine driven, power-generating plants likewise increased. The rise in the number of larger electric generating plants spelled a shift to larger, more powerful pumps.[10]

Table 1. Productivity and related indexes for pump and compressor manufacturing, 1958–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1958	64.5	41.1	63.7	63.1
1959	68.8	43.4	63.1	62.6
1960	66.6	44.6	67.0	66.1
1961	69.2	43.9	63.4	62.6
1962	73.6	48.6	66.0	64.9
1963	78.1	51.7	66.2	64.6
1964	79.4	59.0	74.3	71.5
1965	80.9	65.2	80.6	77.9
1966	81.1	70.5	86.9	82.9
1967	82.5	70.1	85.0	82.4
1968	82.3	68.3	83.0	80.3
1969	86.3	74.0	85.7	83.3
1970	85.8	74.8	87.2	85.8
1971	87.1	69.4	79.7	79.4
1972	91.1	76.2	83.6	82.5
1973	97.8	87.7	89.7	88.6
1974	96.7	94.0	97.2	97.3
1975	91.3	87.0	95.3	96.0
1976	96.8	91.4	94.4	94.3
1977	100.0	100.0	100.0	100.0
1978	102.6	107.1	104.4	105.1
1979	102.5	114.5	111.7	112.7
1980	99.8	112.9	113.1	113.9
Average annual rates of change (in percent):				
1958–80	2.1	4.7	2.6	2.7
1975–80	1.9	6.0	4.1	4.2

Construction accounts for another 18 percent of pump and compressor output. Centrifugal and trash pumps (which accommodate up to 25 percent of small solids in the water being pumped) are used in the clearing and preparing of construction sites.[11] Portable compressors are indispensable in the many pneumatical operations at construction sites. Between 1960 and 1973, the volume of total construction put in place rose at an average annual rate of 2.9 percent; thereafter it declined at a rate of 1.5 percent. However, some construction sectors with high demand for pumps continued to expand—for example, sewage system construction (spurred by more stringent environmental regulations).

Employment and hours

Employment in the pump and compressor manufacturing industry currently numbers approximately 91,000 persons. It rose 81 percent between 1958 and 1980, or at an average annual rate of 2.7 percent (compared with 1.1 percent for all manufacturing).

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The long-term trend in employee hours in the industry did not differ significantly from the long-term trend in employment. They rose at a rate of 2.6 percent a year over the period, compared with 1.1 percent for manufacturing as a whole.

Production worker employment rose somewhat faster over the 1958–80 period than production workers' hours (2.7 percent a year versus 2.4 percent). Year-to-year changes ranged from an increase of 12 percent in 1974 to a decline of 10 percent for production worker employment; the range was wider still for hours. Overtime exceeded the manufacturing durables average in 17 of the 22 years examined here.[12] Comparatively high overtime hours were probably related to hiring and separation policies which, judging by the pertinent labor turnover data, have been such as to ensure retention of a relatively skilled work force. Labor turnover in the industry ran less than three-fifths of the manufacturing average for the period.[13] High overtime and low turnover rates were probably also related to the skill composition of the industry's work force.

Data on the skill composition of employees in pump and compressor manufacturing are not directly available. Such data have been compiled by the BLS only for the general industrial machinery group (SIC 356), of which pumps and compressors represent 29 percent by employment. Craft and related workers accounted for 30 percent of the production workers employed by establishments in this group in 1980, compared with 26 percent for total manufacturing. Metalworking craftworkers represented 12 percent of all production workers in the group, compared with 5 percent for manufacturing; and machinists 3 percent, compared with 1 percent. Operatives accounted for slightly more than three-fifths of all production workers in the general industrial machinery group, the same as in manufacturing as a whole. But metalworking operatives in industrial machinery, constituting one-third of production workers, had three times the share of their counterparts in all manufacturing. Laborers, with 6 percent of production workers in the group, had little more than half their share for all manufacturing.

Wage differentials also suggest a somewhat higher skill composition for production workers in pump and compressor establishments than in all manufacturing. In 1980, hourly earnings of the former ran 10 percent above the manufacturing average, and 3 percent above the manufacturing durables average. These ratios remained substantially unchanged during 1958–80. (Hourly earnings were about the same for production workers in the industry and in the general industrial machinery group of which the industry is part.)

Employment of nonproduction workers by pump and compressor manufacturing establishments rose at a slightly faster rate than that of production workers—2.9 percent a year (versus 2.7 percent). Nonproduction workers account for a comparatively high proportion of the industry's employment—41 percent in 1980, as against 30 percent for all manufacturing. The proportion did not change significantly over the review period. One of the reasons for the high proportion of nonproduction workers resides in the larger share accounted for by mechanical engineers in the industry groups' occupational makeup (the data are, again, for the general industrial machinery group). Such engineers represented 6 percent of all white-collar workers in the group in 1980—three times the comparable manufacturing ratio. Engineering and science technicians, among them drafters, made up 11 percent of white-collar workers in the group, as against 8 percent for manufacturing. The group also employed a somewhat higher proportion of clerical and secretarial workers (42 versus 40 percent). The share of blue-collar nonproduction workers, such as truckdrivers and service employees, was generally lower than for manufacturing.

Technological changes

Small lot production is the rule in pump and compressor establishments. Pumps and compressors are often large machines, manufactured to customer specification. While many of these machines are composed of standard parts, the economies associated with mass production are generally not available in producing pumps and compressors. The production process must constantly be adapted so as to cope with the many design, casting, and machining requirements that arise. Such adaptation was facilitated by the advent of numerically controlled machine tools in the 1960's, and the introduction of computer-aided design into engineering practice.[14] Numerical controls and computer-aided design have been important sources of labor productivity advances in the industry. The impact of these technological changes will be outlined, following a brief survey of the kinds and age of the metalworking machinery used in manufacturing pumps and compressors.

According to the *12th American Machinist Inventory of Metalworking Equipment* for 1976–78 (latest available), about one-third of all metal cutting and metal forming machine tools in the pump and compressor manufacturing industry were less than 10 years old; 70 percent were less than 20 years old. Comparable data for earlier years are available only for the general industrial machinery group (SIC 356). For general industrial machinery, no distinct trend in the age composition of metalworking machinery is observable. Thus, in 1958, 34 percent of such machinery installed in the plants of this group was less than 10 years old, 74 percent was less than 20 years. In 1968, as well as in 1978, the comparable figures read 33 and 72 percent.[15]

Despite the absence of a trend toward a more mod-

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ern stock of metalworking equipment in terms of age, output capability per machine tool unit improved considerably. According to the *American Machinist's 10th Inventory of Metalworking Equipment* (1968), "For the last 5 years, the number of machine tools has increased by 4.5 percent, while the value of production, as measured in constant dollars by the *American Machinist* production index, has gone up by 39 percent." In the text accompanying its 12th Inventory (1976–78), the *American Machinist* again confirmed this trend. It noted that while the total machine tool "population" had declined by about one-tenth between 1968 and 1978, the production index had risen 40 percent.[16]

Table 2. Productivity and related indexes for pumps and pumping equipment manufacturing, 1972–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1972	90.8	81.0	89.2	88.1
1973	94.1	91.7	97.4	94.8
1974	93.6	91.9	98.2	98.3
1975	89.9	90.4	100.6	101.4
1976	92.7	92.9	100.2	99.7
1977	100.0	100.0	100.0	100.0
1978	101.1	106.1	104.9	106.2
1979	100.7	111.6	110.8	113.0
1980	97.2	112.5	115.8	117.6
Average annual rates of change (in percent):				
1972–80	1.2	3.9	2.6	3.1

Machining time cut

The increase in the output capacity of machine tools has undoubtedly contributed to gains in the labor productivity of pump and compressor manufacturing. For example, machining time for pump casings, which often are of great weight and size, has in the leading plants been drastically reduced by specially designed milling machines. These milling machines also require less setup time, and a smaller number of setups than formerly. In one case, machining time for large centrifugal pump casings, weighing up to 18,000 pounds, was reduced from 48 to 17 employee hours; in other words, where three 16-hour shifts, involving two operators, were required earlier, only one operator working 17 hours is needed now.[17] However, electric energy requirements are considerably greater.[18]

Reductions in machining time are frequently achieved by combining in one large metalworking operation several previously separate ones. An example is the simultaneous milling, radial drilling, and facing (smoothing) of different parts of the same workpiece. Sequential operations on a given workpiece are speeded up by means of automatic tool changers, commanded by taped instructions, causing different kinds of tools (or different configurations of the same kind of tool) to be advanced, retracted, and changed, as programmed. (Such apparatus may be bypassed by manual controls, when necessary in the operator's judgment.)[19]

Reductions in setup time have also been made possible for many single-purpose machines, for example, grinders. Pump shafts must in some cases be tapered, and this has usually required several setups depending upon the length and desired fit of the shaft. In some of the industry's plants, separate setups for this purpose have been eliminated by grinders that adapt automatically and will grind several fits simultaneously.[20]

Advances in the foundry operations of pump and compressor manufacturers have also contributed to labor productivity gains. In the technically more advanced plants, molding and coremaking have been speeded up by rapid-cycle machinery, and by discarding the time-consuming sand baking process. The no-bake process uses a resin binder and a catalyst to produce the sand mold, saving energy as well as unit labor requirements.[21] Several of the same core patterns (from which pump casings and other pump and compressor parts are cast) can be cut simultaneously by means of synchronous fabricating machinery, operating on the principle of key-making apparatus.

Engineering plays a key role in pump and compressor manufacturing. As noted, much of the industry's output is manufactured to customer specifications, which of necessity involves engineering staff. Additionally, the advent of numerically controlled machine tools, and of computer numerical controls, has centered more production responsibilities in engineering departments, away from the shop floor. The growth of engineering staff has intensified concern with promoting its efficiency. Engineering efficiency has been raised in the more advanced establishments of the industry by applying certain computer technologies; designing production processes which economize on engineering time; and standardizing common parts. Efforts have also been made to bypass engineering where feasible.[22]

Computer graphics have simplified drafting by allowing corrections to be made to the draft without manually redrawing it. Detailed drawings can be made within minutes, where before it took hours. Computerized data banks permit access to all drawings on file. Computer graphics has permitted the elimination of 7 to 8 drafter jobs in one of the establishments visited by BLS staff. The computer-aided design can be programmed directly upon tape, and fed to the machine tool. This represents a considerable advance for numerical controls, inasmuch as programs previously had to be punched, or prepunched programs had to be purchased.

With design and production closely linked, owing to the computer and numerical controls, engineers conceive of computer-aided design and computer-assisted manufacturing as integral operations. Calculation of formulae, design of the product, and production are

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viewed and operated as a single process. Uniformity of product dimension and quality are ensured. Changes in the detail of design are quickly and inexpensively incorporated. Engineering time saved by computer-aided design and computer-assisted manufacturing has been estimated at two-thirds of conventional engineering procedures.[23]

As noted, replacement of parts and attachments accounts for a sizable proportion of the output of pump and compressor manufacturing. Computer-aided design and computer-assisted manufacturing helps ensure that replacement parts are dimensionally accurate, while economizing on engineering time. Dimensional conformance is further ensured by certain process innovations. Thus, cores or molds for impellers and other pump and compressor components are now frequently ceramic instead of wood.

Capital expenditures

Plant and equipment outlays by pump and compressor manufacturers rose at an average annual rate of 8.1 percent between 1958 and 1980—compared with 4.9 percent per year for all manufacturing. (The expenditure data underlying these rates have been adjusted for price changes.[24]) The industry's capital spending rose at a particularly high rate during the 1960's, nearly tripling between 1958 and 1969. For a few years thereafter, such spending receded from the 1969 level, but it resumed its rise in 1972, and doubled between 1972 and 1980. Comparable figures for all manufacturing are considerably more modest, as the tabulation shows (average annual rates in percent):

	Pumps and compressors	*Manufacturing*
1958–80	8.1	4.9
1958–69	12.2	8.2
1969–80	6.9	4.6
1969–72	-10.2	-3.0
1972–80	7.6	5.4

Structure of the industry

In 1977, pumps and pumping equipment were manufactured in 613 establishments, air and gas compressors in 175. The former had increased 10 percent since 1972, the latter had more than doubled. In the preceding 9 years, no change in the number of establishments making pumps and compressors had occurred. The number of *companies* in the industry owning these establishments barely changed during the 1970's.[25]

Pumps and compressors are manufactured mostly in larger plants. Five percent of all establishments in the industry employed 45 percent of its workers in 1977, and accounted for about the same proportion of the total value of shipments. More generally, establishments with 100 workers or more represented less than one-quarter of the total number of establishments in the industry but well over four-fifths of total employment and value of shipments.

Table 3. Productivity and related indexes for air and gas compressor manufacturing, 1972–80

[1977 = 100]

Year	Output per employee hour	Output	Employee hours	Employees
1972	92.1	66.7	72.4	71.6
1973	106.8	79.8	74.7	76.6
1974	103.0	98.2	95.3	95.3
1975	96.7	80.5	85.0	85.3
1976	106.4	88.4	83.1	83.8
1977	100.0	100.0	100.0	100.0
1978	105.5	109.1	103.4	102.8
1979	106.0	120.3	113.5	112.2
1980	105.7	113.7	107.6	106.6
Average annual rates of change (in percent):				
1972–80	1.1	6.5	5.4	5.2

Concentration was high. The industry's four largest companies employed more than half of its workers in 1977, and accounted for half of its value of shipments. For manufacturing as a whole, the comparable ratios were 6 and 7 percent.

Even so, the establishments are mostly small, employing fewer than 100 persons. The smaller plants accounted for 79 percent (pumps) and 70 percent (compressors) of all industry establishments in 1977. At the same time, however, they recorded only 14 and 9 percent of total industry employment. These relationships had not changed much from earlier phases of the review period.

Outlook

Continued advances in the labor productivity of pump and compressor manufacturing are likely over the longer term. The diffusion of numerically controlled machine tools and computer-aided design within the industry's establishments, as well as among them, has still some way to go. The age distribution of metalworking machinery should continue to favor higher-capacity, modernized equipment. Organizational changes resulting from a widening scope of computer applications—for example, more centralized decisionmaking in reference to machining processes—will probably also improve productivity.[26]

So far, robots appear not to have been introduced widely. Even in the more advanced shops, they are used chiefly for paint spraying and other marginal operations. Industry observers, however, expect that robots, as their costs decline, will handle workpieces more and more during the noncutting portion of the work cycle.[27] Such a development is also bound to raise labor productivity.

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The nearer-term outlook is somewhat clouded, however. The industry's output is likely to suffer from weakened demand from major users of pumps and compressors. When output slackens, a slowed rate of productivity advance, even declines in the rate, are more probable. A source of weakened demand is the stagnation in housing starts, which tends to diminish the need for pumps and compressors used in construction, as well as for such public works as water and sewage, which often require pumps and related equipment on a large scale. Another source of declining needs for (hence output of) pumps and compressors are reductions in projected increases in oilfield exploration and development. (These reductions have been linked to smaller-than-expected energy demand increases, and lessened price pressures.)[28]

At the same time, the widespread concern with cutting energy costs may bolster the demand (and output) of more energy-efficient pumps and compressors. For example, variable displacement pumps may to some extent replace fixed displacement pumps. The latter rejects excess flows by means of a relief valve, dumping them back into a reservoir. This wastes pump energy, which a variable displacement pump can avert.[29] Piston pumps, furthermore, are thought by industry observers to be also favored over fixed displacement pumps, as high-pressure hydraulics is more widely adopted in industry and transportation (especially in aircraft and mobile equipment). High-pressure hydraulics permits the use of lighter pipes, pumps, and actuators.[30]

Industry observers believe that pumps and equipment of larger size will continue to be installed in such uses as steampower generation, pipelines, and petroleum refining. The shift from gasoline to heavy fuel refining[31] requires heavier rotary rather than lighter centrifugal pumps. Slurry pipelines—which move water-suspended solids such as coal and wood chips—are believed to gain wider acceptance, because they offer important economies in transportation.

The BLS has projected a somewhat faster rise in the number of nonproduction workers than production workers for the general industrial machinery group.[32] In 1990, professional and technical workers will make up 12.4 percent of all of the group's employees, according to the projections, compared with 11.4 percent in 1980; and the share of clerical and related workers will rise slightly. The proportion of craftworkers will remain unchanged, and that of operatives will edge downward. It seems reasonable to assume that changes in occupational pattern projected for the general industrial machinery group will, by and large, be repeated by pump and compressor manufacturing.

[1] The pump and compressor manufacturing industry consists of two segments, pumps and pumping equipment, designated as SIC 3561 of the *Standard Industrial Classification Manual 1972* of the Office of Management and Budget; and air and gas compressors, SIC 3563. SIC 3561 consists of establishments primarily engaged in manufacturing pumps and pumping equipment for general industrial use. Measuring and dispensing pumps for gasoline stations are not included, nor are pumps installed in automobiles. SIC 3563 consists of establishments primarily engaged in manufacturing air and gas compressors for general industrial use. Refrigeration compressor units are not included. Prior to 1972, pumps and compressors were classified together in SIC 3561.

Average annual rates of change are based on the linear least squares of the logarithm of the index numbers. Extensions of the indexes will appear in the annual BLS Bulletin, *Productivity Measures for Selected Industries.*

[2] William C. Krutzsch, "Introduction and Classification of Pumps," in Igor J. Karassik and others, *Pump Handbook* (New York, McGraw-Hill, 1973), p. 1 ff.

[3] John P. Rollins, ed., *Compressed Air and Gas Handbook* (New York, Compressed Air and Gas Institute, 1973), p. 1. The range of compressed air uses are discussed on pp. 1–44.

[4] U. S. Department of Commerce, Bureau of Economic Analysis, *The Detailed Input-Output Structure of the U. S. Economy: 1972* (Washington, D.C., Government Printing Office, 1979).

[5] John R. Birk and James H. Peacock, "Chemical Industry," *Pump Handbook*, p. 10–74 ff. Also, conversation with industry observer.

[6] E. R. Pritchett, "Steel Mills," *Pump Handbook*, p. 10–159; and telephone conversation with author.

[7] Elvitsky, *Pump Handbook.*

[8] U. S. Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries, 1954–80* (Washington, D.C., Government Printing Office, 1982), table 179.

[9] Mary Vickery, "Petroleum Pipeline Transportation," U.S. Department of Labor, Bureau of Labor Statistics, *Technological Change and its Labor Impact in Five Energy Industries*, BLS Bulletin 2005 (Washington, D.C., Government Printing Office, 1979), pp. 39 and 42.

[10] Telephone conversation with Krutzsch, an author of *Pump Handbook.*

[11] Benjes, H.H., "Sewage," *Pump Handbook*, p. 10–2. Also, telephone conversation with author.

[12] Overtime in pump and compressor manufacturing compared with overtime for all of manufacturing durables (all manufacturing = 100) as follows:

	Pumps and compressors		*Pumps*	*Compressors*
1958	63	1974	126	112
1959	111	1975	119	115
1960	104	1976	131	103
1961	83	1977	114	116
1962	96	1978	100	113
1963	90	1979	103	114
1964	103	1980	100	161
1965	113			
1966	123			
1967	114			
1968	103			
1969	103			
1970	110			
1971	93			
1972	103			
1973	105			

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[13] Labor turnover in pump and compressor manufacturing compared with manufacturing (all manufacturing = 100) as follows (data from 1972 forward for pumps and pumping equipment only; data for air and gas compressors are not available):

	Accessions	*Separations*
1958	52	66
1959	69	56
1960	55	65
1961	54	58
1962	56	51
1963	56	56
1964	63	46
1965	60	58
1966	68	63
1967	57	59
1968	57	57
1969	68	65
1970	60	76
1971	54	56
1972	60	49
1973	67	55
1974	71	67
1975	51	68
1976	59	53
1977	63	55
1978	51	49
1979	53	54
1980	54	58

[14] See Comptroller General of the United States, *Manufacturing Technology—A Changing Challenge to Improved Productivity*, Report to the Congress, Washington, June 3, 1976, especially p. 37 ff.

[15] *The Eighth American Machinist Inventory of Metalworking Equipment—1958*, New York, McGraw-Hill. Reprinted from the *American Machinist*, Nov. 17, 1958; *The Tenth American Machinist Inventory of Metalworking Equipment—1968*, New York, McGraw-Hill, 1968. The data cited for pump and compressor manufacturing from the 12th *Inventory* are based on unpublished printouts.

[16] *American Machinist*, December 1978, p. 135. The reduction in machining time is confirmed in Donald N. Smith and Larry Evans, *Management Standards for Computers and Numerical Controls* (University of Michigan, 1977). See also John Duke and Horst Brand, "Cyclical Behavior of Productivity in the Machine Tool Industry," *Monthly Labor Review*, November 1981, pp. 27–34.

[17] William H. Parker, "Cutting time out of pump machining," *American Machinist*, January 1979, pp. 112–13.

[18] "The Machine Tools that are Building America," *Iron Age*, Aug. 30, 1976, p. 163. According to the report, electric horsepower requirements for lathes rose from 150 in the 1950's to 400 to 600 in the 1970's. Many other examples are also cited in the article.

[19] Observation of industry operations. See also *Iron Age*, cited above.

[20] Observation of industry operations.

[21] Observation of industry operations. See also Richard W. Lyon, "Foundries," in U.S. Department of Labor, Bureau of Labor Statistics, *Technology and Labor in Four Industries*, Bulletin 2104 (Washington, D.C., Government Printing Office, January 1982), p. 12.

[22] Industry sources, and observation of industry operations. See also A. Harvey Belitsky, "Major technology changes in metalworking machinery," *Technology and Labor in Four Industries*, pp. 20–33.

[23] Industry source.

[24] Adjustment for price changes was made by using the implicit deflator for nonresidential investment in structures and producers' durable equipment. See *Economic Report of the President*, February 1982, p. 236.

[25] U.S. Department of Commerce, Bureau of the Census, *General Report on Industrial Organization, 1977 Enterprise Statistics* (Washington, D.C., Government Printing Office, 1981).

[26] A. Harvey Belitsky, "Major technology changes," especially pp. 24–25.

[27] See *American Machinist*, June 1980, p. 147 ff.

[28] "Biggest U.S. Oil Concerns Likely to React to Glut by Cutting 1982 Capital Budgets," *The Wall Street Journal*, Apr. 7, 1982, p. 7.

[29] "Curbing the Energy Appetite of Hydraulic Systems," *Machine Design*, June 26, 1980, p. 95.

[30] "Modern Hydraulic Systems: the Pressure Mounts," *Machine Design*, Jan. 24, 1980, p. 81 ff.

[31] Rose Zeisel and Michael D. Dymmel, "Petroleum refining," *Technological Change and Its Impact in Five Energy Industries*, p. 26.

[32] See the articles on the Bureau's projections in *Monthly Labor Review*, August 1981, pp. 9–42.

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Output per unit of labor input in the retail food store industry

Productivity, as measured by output per hour of all persons, increased 2.4 percent annually during 1958–75, because of industry structural changes and some technological improvements

JOHN L. CAREY AND PHYLLIS FLOHR OTTO

Output per hour of all persons in the retail food industry increased at an average annual rate of 2.4 percent from 1958 to 1975, compared with a gain of 2.3 percent for the nonfarm business sector.[1] This growth reflect increases of 2.4 percent in output and 0.1 percent in hours.

Growth in output per hour of all persons has been influenced by a trend to fewer and larger stores serving a growing population, a corresponding decline in the number of small stores, as well as some changes in technology and store operations designed to increase efficiency. The decline in the number of small stores has led to decreases in the number of partners, proprietors, and unpaid family workers in the industry, which has counteracted the increase in the number of paid employees. Hours of paid employees grew at an average rate of 1.9 percent from 1958 to 1975, offsetting the decline of 4.5 percent per year in the hours of the self-employed and unpaid family workers.

There are widely disparate growth rates in the two components of the retail food store industry. From 1958 to 1975, the output of grocery stores (which comprises the largest portion of the industry and includes supermarkets as well as small grocery stores) increased at an average rate of 2.8 percent each year. Specialty food stores (such as bakeries and meat markets) averaged only 0.7 percent each year. The number of specialty stores continued to decline as they lost business to supermarkets, which offer similar products with the convenience of one-stop shopping. On the other hand, supermarkets have lost some business to the convenience food stores. Although many items are higher priced, these stores are conveniently located and provide fast service.

Efficiency in the retail food industry has been aided by improvements in displaying merchandise and electronic innovations, such as computerized scales and cash registers. Also contributing to efficiency is the trend toward prepackaging merchandise at the distributor, cutting and packaging poultry at a centralized location, and price marking at the warehouse.

Trends in output per hour

During 1958–72, output per hour showed increases, ranging from 1.2 to 5.5 percent, every year except 1969, when a decline occurred. (See table 1.) During 1958–72, the average annual rate of increase was 3.0 percent. (In the nonfarm business sector the rate for the same period was 2.6 percent.) However, as shown in the following tabulation, the 1973–74

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recession slowed the growth to an average annual rate of 2.4 percent for 1958–75:

	Output per hour of all persons	*Output*	*Hours of all persons*
1958–75	2.4	2.4	0.1
1958–72	3.0	2.8	−.2

In the overall economy, the period 1958–72 was marked by increasing per capita income, relatively stable prices (the Consumer Price Index rose at an average annual rate of 2.7 percent), and increasing per capita food consumption. Retail food store output increased every year. From 1958–72, people continued to switch from small food stores to supermarkets and the average supermarket became larger, as firms closed their small, inefficient operations. The number of retail food stores fell 26 percent from 1958 to 1972. Grocery stores with sales greater than $500,000 a year increased their share of total retail food store sales from 51 percent in 1958 to 70 percent in 1972.[2]

Supermarkets accounted for almost 76 percent of all grocery store sales and about 70 percent of all retail food store sales in 1972. Today, nearly 9,000 items are sold in supermarkets—a 50-percent increase since 1960. This vast number of items, along with the procedures that are necessary to order, stock, and market them have acted to limit the gains in output per hour. However, this has been offset to some extent by an upward trend in the size of the average customer transaction. Although precise figures are not available, estimates indicate that the average supermarket sale, adjusted for changing price levels, increased about 10 percent from 1958–71, though it has dropped each year since then.[3]

Because most products can be packaged in different sizes, packaging practices by the manufacturer have an effect on the utilization of labor in retail food stores. For example, economy size packages result in a larger volume being sold in a single transaction. In a similar fashion, disposable cans and bottles have largely superseded deposit bottles and eliminated much handling time. However, the growing concern with environmental and conservation factors may reverse this trend.

In 1973 and 1974, as the economy moved into a recession, coupled with large increases in food prices, output per hour fell in retail food stores—5.1 percent in 1973, and an additional 2.1 percent in 1974. Output fell 3.3 and 0.5 percent, respectively; despite this drop, hours rose in both years, 1.8 percent in 1973, and 1.6 percent in 1974. Food prices, as measured by the Consumer Price Index for food at home, soared 16 percent and 15 percent in 1973 and 1974, higher than increases in per capita disposable income (12 and 8 percent). Among the reasons for the increase in hours (despite the drop in output) was the continued industry trend toward Sunday openings, the longer hours of operation during the week, and the growth of service-oriented operations in supermarkets.

As the economy began to improve in 1975, output per hour in the retail food store industry recorded a gain of 2.7 percent—output grew 0.8 percent and hours declined 1.9 percent, as hours of employees fell slightly and the hours of partners, proprietors, and unpaid family workers continued their historic movement downward. Per capita disposable income rose 9 percent in 1975 as compared with the slightly lower gain of 8 percent in food prices.

Table 1. Output per hour of all persons and related data, retail food stores, 1958–75

[1967=100]

Year	Output per hour of all persons	Output	Hours of all persons
1958	75.4	78.4	104.0
1959	78.4	81.9	104.4
1960	80.9	84.1	103.9
1961	84.0	86.1	102.5
1962	85.3	88.0	103.2
1963	89.4	88.7	99.2
1964	91.4	93.0	101.8
1965	93.8	96.4	102.8
1966	96.3	98.0	101.8
1967	100.0	100.0	100.0
1968	105.1	104.6	99.5
1969	104.8	105.6	100.8
1970	110.5	111.7	101.1
1971	111.9	114.1	102.0
1972	113.3	116.8	103.1
1973	107.5	112.9	105.0
1974p	105.2	112.3	106.7
1975p	108.1	113.2	104.7

p=preliminary.

Employment and hours

The total number of persons working in retail food stores increased 21 percent from 1958–75, while total hours increased less than 1 percent. This disparity can be attributed directly to the growth of part-time help, along with the decline in the number of partners, proprietors, and unpaid family workers in the retail food industry. The average weekly hours for nonsupervisory workers fell from 36.3 in 1958 to 32.3 in 1975, even though there was a general trend to longer store hours and Sunday sales. In June 1966, part-time help accounted for over 40 percent of the work force in retail food.[4] Today, one survey shows that part-time help accounts for over 50 percent of the work force in supermarkets.[5]

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The 21–percent increase in the number of persons engaged in retail food sales consists of a 54–percent increase in the number of paid employees (nearly 2.0 million in 1975) offset by a 52–percent decrease in the number of partners, proprietors, and unpaid family workers (272,000 in 1975). Partners, proprietors, and unpaid family workers now account for only about 12 percent of the total number, as compared with 31 percent in 1958. Some of the decrease in the number of partners and proprietors may be due to changes in business organization. (For example, a number of firms may have incorporated and the partners or proprietors may have become paid employees, but there are no specific data on the change.) It is believed, however, that most of the decline was due to the decrease in the number of single–store firms—a 34-percent decline from 1958 to 1972.

Retaining experienced personnel is a major problem confronted by retail food stores. Labor turnover is extremely high. In 1968, the overall separation rate for supermarkets was over 60 per 100 employees.[6] (In comparison, the separation rate for the manufacturing sector is around 4 to 5 per 100 employees.) In 1971, the highest turnover among full–time supermarket employees was in cashiers (14 separations per 100) and meatcutters (10 separations per 100). Turnover in store managers was negligible.[7] The high turnover rate among store employees is one of the factors hindering the gain in output per hour in this industry, as new employees must be trained and, therefore, are not as productive during the training period as more experienced persons.

One factor that might be contributing to the high turnover is the low hourly earnings in retail food. In 1975, wages in retail food stores were 13 percent below the hourly average for the total private nonagricultural sector, and 18 percent lower than the manufacturing average.

Changes in industry structure

Retail food distribution has been dominated for quite some time by supermarkets. Supermarkets came into existence around 1930 and were well established by the beginning of World War II. Growth was slowed during the war but increased rapidly during the postwar years. Supermarkets combine the functions of separate establishments (or specialty stores) which, for the most part, are small and independently owned.

Small specialty stores and grocery stores account for a large portion of employment, about 30 percent in 1972. While a supermarket usually employs 25 to 75 people, the average number of paid employees in all retail food stores with employment was 10 in 1972. More than 30 percent of the retail food stores are operated entirely by proprietors or partners and, therefore, have no paid employees.

Most supermarkets are in suburban locations—frequently in shopping centers. Eighty percent of the supermarkets opened in 1971 were located in shopping centers, compared with 47 percent in 1958. Developers of shopping centers are usually willing to lease sites only to firms with high financial ratings, making it difficult for small grocery stores to lease space.[8]

To generate traffic and increase sales within the store, many supermarkets have installed large specialty food and nonfood departments. Bakeries, delicatessens, pharmacies, and liquor departments are common. Although longer hours and Sunday sales are the most visible changes, services, such as check cashing, money orders, film processing, and catering services are now provided by many supermarkets.

Consumers choose to shop in supermarkets rather than small, proprietor–run stores for many reasons. Small stores frequently cannot compete with large stores on price and variety of selection because their low sales volume and small space limit volume discounts. In addition, many chains[9] own some of their own production facilities, or carry private label goods which usually are offered at a lower price than widely advertised, national brand name goods. Some independent stores are able to overcome price problems by joining or forming a wholesale affiliation group (voluntary or cooperative chain), which can obtain volume discounts for all the member stores. Frequently, they also carry some types of private label goods.

Voluntary chains lack in-store data about trading areas and customer shopping habits, but have more flexibility with respect to store locations than corporate chains. Corporate chains operate in a consistent manner and the use of experimental tests can be conducted in a controlled environment.[10]

The small retailer who does not belong to a chain generally pays higher prices for merchandise; therefore, in order to compete, the retailer must be very efficient or provide a service not readily available in a supermarket. A significant number of speciality stores and small grocery stores survive by locating in areas which are not profitable for large retailers (such as inner city, high–density areas, and large apartment buildings) because some customers are willing to pay extra for service or credit.

A new trend in food retailing is the growth of small (2,000–4,000 sq. ft.) convenience food stores. These stores, located primarily near residential ar-

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eas, provide the consumer with ease of access, quick selection, and virtually immediate checkout. Items requiring extensive labor time, such as fresh meat and most fresh produce, are not carried. The selection is much smaller than in a supermarket; in fact, four products (tobacco, beer and wine, soft drinks, and dairy products) make up more than one–half of the sales of one convenience store chain.[11]

Convenience stores grew rapidly during the late sixties. Their net profits before taxes were 4.8 percent of retail sales in 1974—double that of independent supermarkets.[12] These stores are supplied largely by outside wholesalers and distributors rather than by their own warehouses.

Changes in technology and store operations

Technological developments, including changes in distribution practices, have been a source of improvement in output per hour in this industry. The technological changes that occurred during 1958–75 were small improvements, rather than innovations that greatly altered store operations. Among such improvements were refrigeration systems with fast defrost, self-defrosting freezers, special surface floors in the meat department that help to reduce cleanup time, and faster meat slicers and grinders. Other improvements included meat wrapping machines, shrink and heat pressure wrapping film, and scales that automatically print a weight and price tag.

Improvements have also been made in display techniques. Produce, for example, is now kept in refrigerated display cases, eliminating the need to remove the perishable produce to the back room each night. Other changes include standup refrigerator cases with doors that face the customer and backs that open into a refrigerated storeroom. (A variation is the roller cart which can be placed in a refrigerator case direct from delivery.) Other techniques include the use of cardboard display cases provided by manufacturers and "dump" displays where goods are simply put in wire baskets in no particular order.

Most supermarkets are arranged so that the typical customer will have to walk though most of the store to buy groceries. (Exposing the customer to the full array of products encourages larger transactions.)

Certain manufacturing and distribution techniques have also aided growth in output per hour of all persons within the retail food store. The use of shrink film (a form of clear plastic wrap) rather than complete cardboard cartons has decreased the time spent opening boxes and disposing of waste cardboard. Shrink film also allows instant identification of merchandise.

Also affecting the utilization of labor, are trends toward prepackaged produce, precut and packaged poultry, and some increase in centralized cutting and packaging of fresh meat. These trends vary greatly, however, because consumer acceptance has not been uniform. For example, although much more produce is wrapped by distributors and growers than in the past, most retailers continue to display, package, and weigh more than half of their produce within individual stores. On the other hand, precut and prepackaged poultry has gained wide consumer acceptance; in fact, much of the poultry now sold in retail food stores is cut, packaged, and weighed at poultry processing plants.[13]

At the present time, most meat is cut and packaged at the retail store, after it has been broken into primal and subprimal cuts at a centralized location. Only about 3 percent of the firms operating retail markets have centralized the cutting and packaging of final cuts. Frozen meat, which can be cut, packaged and shipped by the meatpacking plant, has not gained sizable consumer acceptance.[14]

Other changes in technology include the use of conveyor belts in the warehouse and overhead "railway" systems for unloading and transporting sides of beef. Central warehouses are used more efficiently now because computers are used for inventory control and space management as well as for forecasting sales.

Detrimental to the growth in output per hour of all persons over the period studied was the time spent by employees issuing stamps and games to customers. Although this trend has been replaced by the use of coupons and foods stamps by shoppers, the effect remains the same—increased checkout time. New shopper aids, such as unit pricing, also can slow growth in output per hour during periods of rapid price changes because of the additional number of labels that have to be changed.

Outlook

A growing trend in the retail food industry is the emergence of the combination or "superstore" with a large nonfood department. This department may cover 40 to 50 percent of the total selling area. Total space in these "superstores" is around 40,000–50,000 square feet, or twice the size of the average supermarket today. One trade association reported that 9 percent of all supermarkets opened in 1973 were combination stores. Conventional stores, however, still account for over 95 percent of all supermarkets.[15]

The trend toward central, as opposed to retail, meat cutting may grow. The primary advantage is the reduction in labor time at the retail level. With

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central meat cutting, the waste problem is reduced and retailers can be more specific in their orders.[16]

Electronic cash registers and the uniform product code are beginning to be used in retail food stores. With this system, a unique, machine–readable symbol is placed on each product, and is translated into a price by an optical scanner. The price can be read on a screen and the data are then transmitted to a computer which prints out a detailed receipt for the customer. In the most prevalent system, the checker runs the symbol over the optical scanner and bags at the same time, decreasing checkout time for shoppers. In addition to eliminating cashier errors, the computer can also keep inventory automatically and assist in reordering for the store when levels decline to a predetermined point. Labor savings can be obtained by eliminating the need to mark prices on items, and to take inventory manually. Training time for cashiers can also be reduced significantly. The development of scales for weighing and simultaneously marking meat and produce with the uniform product code symbol will assist the diffusion of this technology. The main obstacle to the immediate use of this system is the high cost of the registers and computers. Also, there have been some objections to the lack of price markings on individual items. Retailers may have to continue to mark prices, thereby losing some of the labor saving advantages of this system.

[1] The study covered paid and unpaid persons (including paid employees, partners, proprietors, and unpaid family members) working in retail food establishments. (Data for 1974 and 1975 are preliminary.) Retail food stores are defined as those establishments primarily engaged in selling food for home preparation and consumption (major group 54 in the 1972 Standard Industrial Classification Manual). All average annual rates of change are based on the linear least squares trend of the logarithms of the index numbers. Current indexes for this industry are published in the annual BLS bulletin, *Productivity Indexes for Selected Industries.*

[2] The definition of supermarkets in terms of annual sales volume differs among industry sources. The amount of $500,000 is used by the Department of Agriculture and some trade publications. The Super Market Institute, however, uses a $1 million annual sales volume. Discussions and data pertaining to that source in this article, therefore, should be viewed with the difference in mind.

[3] See annual issues of *The Super Market Industry Speaks* (Super Market Institute, Inc.). This should be interpreted with care since many factors can influence the size of a transaction—number of trips to the store per week and shifts to higher (or lower) valued merchandise, for example.

[4] *Employee Earnings and Hours in Retail Food Stores,* Bulletin 1584–3, (Bureau of Labor Statistics, 1968).

[5] See *The Super Market Industry Speaks: 1969* (Super Market Institute, Inc.) p. 25.

[6] *Super Market Industry Speaks: 1969,* pp. 25–26.

[7] *Super Market Industry Speaks: 1972,* pp. 15–16.

[8] See *Food: From Farmer to Consumer* (National Commission on Food Marketing), pp. 69–83.

[9] The definition of a "chain" differs among industry sources. A chain is usually considered to be either 4 or more, or 11 or more stores under some form of common operation or control.

[10] Saul B. Cohen, "Location Research Programming for Voluntary Food Chains," *Economic Geography,* January 1961, pp. 1–11.

[11] See "The Threat to Southland's Growth," *Business Week,* Oct. 28, 1972, pp. 60–62.

[12] See "Forty-second Annual Report of Grocery Industry," *Progressive Grocer,* April 1975.

[13] See *The Chicken Broiler Industry: Structure, Practices, and Costs,* Marketing Research Report 930 (U.S. Department of Agriculture, Economic Research Service), May 1971, p. 34.

[14] See "Chain Store Age 1972 Meat Study," *Chain Store Age,* November 1972, beginning on page 55.

[15] *Super Market Industry Speaks: 1972,* p. 10.

[16] See "Central Cutting: The Only Way to Go," *Chain Store Age,* November 1972, beginning on page 72, and "Central Prepackage Meat Operations Holds Line On Expenses for a Three-Store Organization," *Progressive Grocer,* February 1961, beginning on page 50.

APPENDIX: Measurement techniques and limitations

Indexes of output per hour of all persons measure the change in the relationship between the output of an industry and the hours expended on that output. An index of output per hour is derived by dividing an index of output by an index of industry hours.

The preferred output index for retail trade industries would be obtained from data on quantities of the various goods sold by the industry, each weighted (that is, multiplied) by the employee–hours required to sell one unit of each good in some specified base period. This concept also embodies the services associated with moving the goods from the retail establishment to the consumer. Thus, those goods which require more retail labor are given more importance in the output index.

Data on the quantities of goods sold usually are not available for trade industries, including retail food. Therefore, real output was estimated by removing the effects of changing price levels from the current dollar value of sales. This technique was used at various levels of aggregation for both grocery stores and for specialty food stores. Because an adjustment for changing price levels usually lowers the dollar value, such a series is usually referred to as a deflated value measure. Output measures based on deflated value have two major char-

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acteristics. First, shifts in sales can occur among products of different value which have the same unit labor requirements. (For example, if customers begin to purchase more "nationally advertised" brands instead of store brands, dollar sales will increase if the "nationally advertised" brand is priced higher.) Thus, a change can occur in the output per hour index even if the labor required to sell the merchandise does not change.

Second, the sales level, both in current and constant dollars, reflects differences in unit values for identical products sold in different types of establishments. For example, the unit values associated with a product sold in a self-service "discount" store may be lower than the unit value associated with the same product sold in a store that provides many sales clerks and delivery service. The output measure, therefore, reflects changes in the level of service provided to customers insofar as differences in unit values reflect the differences in service among the various types of establishments.

In addition to the deflated value technique, weights relating to labor importance (that is, labor cost and employment) were used to combine segments of the output index into a total output measure. These procedures result in a final output index that is closer, conceptually, to the preferred output measure.

The index of hours for the retail food industry is for all persons—that is, hours for paid employees, partners and proprietors, and unpaid family workers. As in all of the output per hour measures published by the Bureau of Labor Statistics, hours and employment in retail food stores are each considered homogeneous and additive. Adequate information does not exist to separately weight the various types of labor.

The indexes of output per hour relate total output to one input—labor time. The indexes do not measure the specific contribution of labor, capital, or any other single factor. Rather, they reflect the joint effect of many interrelated influences such as changes in technology, capital investment, capacity utilization, store design and layout, skill and effort of the work force, managerial ability, and labor management relations.

No explicit adjustments were made to the measure for retail food to take into account increases or decreases in service provided to the consumer. With the growth of supermarkets and convenience food stores, there has been a continuation of the trend to self-service operations. This has shifted some of the hours in retailing from the employee to the consumer. However, data are not available to measure the impact of this change. Likewise, adjustments could not be made for changes in the quality of products sold. Such adjustments are implicit, however, to the extent that changes in quality have been accounted for in the price indexes used to deflate the current dollar value of sales.

In the noncommodity producing sector, there are many more conceptual problems with the definition of an industry's "output" than in most other sectors of the economy. There are differences of opinion about many of these concepts. One problem is the definition of quality change. In the retail food industry, for example, soft drinks are now sold largely in cans and "no return" bottles, while previously they were sold in deposit bottles. This can be treated as a factor that aids output per hour of all persons because cans and "no return" bottles eliminate much handling time in the store. Such packaging, however, can also be considered as a change in quality to the consumer, and, therefore, a different product requiring an adjustment to the measure. In any case, available data did not permit adjustments to be made for this change.

Other changes in store operations can also affect the utilization of labor. The shift to produce, poultry, and other products that are prepackaged by food processing industries eliminates much retail labor time. Although the available data do not allow adjustments to be made each year, the measure is adjusted periodically through the use of relative labor importance weights. This reduces the possibility for bias in the measure, but does not, of course, eliminate it entirely.

The basic sources for the output series for this measure consist of the total sales data and sales by merchandise line data reported by the U.S. Department of Commerce. The deflators were developed using various Consumer Price Indexes published by the Bureau of Labor Statistics. The labor importance weights were developed from data reported by the U.S. Department of Commerce and the U.S. Department of Agriculture.

The basic sources for the all-persons-hour series consist of data on employment and hours published by the Bureau of Labor Statistics, supplemented by data reported by the Internal Revenue Service and special tabulations compiled for the Bureau of Labor Statistics by the Bureau of the Census.

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The productivity trend in the soaps and detergents industry

During 1958–77, annual productivity increased an average of 2.9 percent, as the industry responded to a strong demand for soap and detergent products and was aided by improved technology

PATRICIA S. WILDER

Productivity in the soaps and detergents industry has increased in line with the rise in output per employee hour for the manufacturing sector since 1958.[1]

While annual output doubled, employee hours increased by more than one-fourth between 1958 and 1977. The average annual increase in productivity was 2.9 percent.

The rise in productivity was associated with an annual increase in output of 4.1 percent coupled with a 1.2-percent average annual increase in employee-hours. Productivity gains have resulted primarily from sustained high levels of capital investment for new machinery and equipment, and improvements in production and packaging operations.

Output per employee hour has fluctuated during the period of this study. Since 1958, annual increases in productivity have ranged from 1.0 to 10.6 percent. Declines in productivity have occurred in 4 years, including 1977. For the most recent 5-year period, 1973–77, productivity has declined at an annual rate of 0.6 percent. (See table 1.)

From 1958 to 1965, average growth in productivity was 1.9 percent; output rose 4.6 percent, and hours advanced 2.7 percent annually. During this period, the industry experienced a general expansion. The number of establishments manufacturing soaps and detergents increased from 608 in 1958 to 704 in 1963.

From 1965 to 1974, productivity grew much faster, averaging 4.3 percent each year. The acceleration was in sharp contrast to the productivity movements of other industries in the economy. More than two-thirds of the industries for which productivity measures are available showed slackening productivity growth since 1966. Productivity growth in the soaps and detergents industry during 1965–74 reflected average annual increases of 4.9 percent in output and 0.6 percent in employee-hours. The slower growth in employee-hours was associated with an overall decline in the number of establishments—from 704 in 1963 to 642 by 1972.

In 1975, a recession year, productivity fell 7.1 percent. Output recorded its largest decline of 9.4 percent, and employee-hours declined 2.4 percent. In 1976, productivity growth resumed with a 3.0 percent gain with both output (5.8 percent) and hours (2.8 percent) increasing over the depressed levels of the preceding year. In 1977, however, output growth slowed to 2.2 percent, while employee hours increased 2.8 percent. This resulted in a 0.6-percent decline in productivity.

Output doubles

Productivity gains in the soaps and detergents industry have been closely linked to output expansion, which doubled between 1958 and 1977. Some significant factors affecting this growth are expanded use of home laundry equipment and dishwashing appliances, population growth, and successful advertising and sales promotions.[2]

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Table 1. Productivity and related indexes for the soaps and detergents industry, 1958–77

[1967 = 100]

Year	Output per employee-hour			Output	Employee-hours		
	All employees	Production workers	Nonproduction workers		All employees	Production workers	Nonproduction workers
1958	77.7	78.3	76.3	64.7	83.3	82.6	84.8
1959	84.4	85.4	82.2	71.8	85.1	84.1	87.3
1960	81.7	81.5	82.0	71.9	88.0	88.2	87.7
1961	82.6	81.7	84.2	75.7	91.7	92.6	89.9
1962	83.9	81.7	89.7	78.8	93.9	96.5	87.8
1963	90.7	87.5	98.8	85.2	93.9	97.4	86.2
1964	90.7	88.3	96.5	88.7	97.8	100.4	91.9
1965	88.1	87.0	90.7	88.5	100.4	101.7	97.6
1966	94.2	94.0	94.6	93.8	99.6	99.8	99.2
1967	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1968	101.1	102.4	98.2	106.0	104.8	103.5	107.9
1969	101.1	104.1	95.0	109.9	108.7	105.6	115.7
1970	105.7	110.4	96.3	115.3	109.1	104.4	119.7
1971	108.6	114.8	96.5	111.7	102.9	97.3	115.7
1972	120.0	125.1	110.1	125.9	104.9	100.6	114.3
1973	127.5	134.4	114.2	135.1	106.0	100.5	118.3
1974	132.7	139.6	119.3	137.9	103.9	98.8	115.6
1975	123.3	129.0	112.1	125.0	101.4	96.9	111.5
1976	127.0	135.0	112.0	132.3	104.2	98.0	118.1
1977	126.2	135.6	109.1	135.2	107.1	99.7	123.9
	Average annual rates of change (in percent)						
1958–77	2.9	3.4	1.9	4.1	1.2	0.7	2.1
1973–77	−0.6	−0.2	−1.5	−0.4	0.2	−0.2	1.1

The growth in output has also been influenced by the availability of a wide variety of soap and detergent products which can handle different types of cleaning problems. Among synthetic detergent products are light-duty, mild, sudsing detergents mainly used for dishwashing by hand; all-purpose and heavy-duty laundry detergents, which can be used for a number of tasks; presoak products; and automatic dishwashing detergents. Laundry soaps are also available as flakes and blown granules. The predominantly used soap product is the refined bar of toilet soap. As shoppers are aware, these bars are available in a variety of sizes, colors, and scents, some containing additives such as cold creams and deodorants. The industry is very competitive and has been able to gain public acceptance of new products through advertising, and by dispensing free samples in large numbers when new products are introduced.[3]

The growth in output has also been influenced by the interactions among the household laundry equipment, textile, and detergent industries. The development of permanent press garments in the mid–1960's by the textile industry was followed by reformulations in detergent products. Because oily soils are more difficult to remove from synthetic fibers, their increased use in clothing required improved detergent products. Also, because higher wash temperatures may cause oily soils in some synthetics to become "set," lower wash temperatures are often recommended for wash and wear garments.[4] The detergent industry developed improved products that would perform adequately at lower wash temperatures. The household laundry equipment industry followed the development of permanent press garments within a few months by the introduction of properly matched cycles in washers and dryers to handle this new concept in clothing.[5] At present, many automatic washers include permanent press cycles and various combinations of wash and rinse temperatures.

The increase in the sales of home laundering equipment, as well as the increase in wash and wear fabrics, favorably affected the demand for soap and detergent products. The output of the household laundry equipment industry is estimated to have increased nearly 70 percent between 1958 and 1976. In 1975, more than 4 million home washing machines were sold, increasing market penetration to 70 percent, from 53 percent in 1960.[6]

Employment shows moderate rise

Employment in the soaps and detergents industry, currently at 40,000, has increased moderately since 1958, when employment was at 32,000. This change is equivalent to an average increase of 1.1 percent each year. The growth in employee hours—an average annual rate of 1.2 percent—reflected a very small increase in average hours per employee.

Labor turnover in the industry has been comparatively low, providing a stable and experienced work force. Since 1958, accessions have averaged 2.5 per 100 employees annually, compared with 3.6 for all manufacturing. Separation rates have been 2.4 per 100 employees, compared with 4.1 for all manufacturing. Lower layoff and quit rates occurred in the industry than for all manufacturing almost every year. Average hourly earnings for production workers in the soaps and detergents industry have risen steadily. Hourly earnings averaged $7.81 in 1977, compared with the manufacturing average of $5.68.

The proportion of nonproduction workers in the industry is somewhat higher than is the case in other manufacturing industries—37 percent of total employment in 1977, compared with 28 percent for all manufacturing. The higher proportion reflects the larger number of professional and technical, clerical, and sales personnel employed.

Although data on the occupational composition of employees in the industry are not available, some insights can be obtained from the broader aggregation, soaps and cosmetics.[7] In 1976, an estimated 6 percent of all workers employed in soaps and cosmetics were chemical and industrial engineers, chemists, and chemical technicians. Sales and clerical personnel accounted for 26 percent of total employment. The industry also employs a large number of semi-skilled workers, such as packers, wrappers, examiners, assemblers, and mixers who accounted for 32 percent of the work force in 1976.

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Larger plants dominate output

Most of the soaps and detergents industry's output is produced by large establishments. By 1972, more than 80 percent of the value of shipments was accounted for by units having 100 employees or more. These units represented only 9 percent of the industry's establishments because most of the industry's establishments are small. In 1972, 69 percent of the 642 manufacturing establishments had fewer than 20 employees.

Prior to the introduction of synthetic detergents, the soaps and detergents industry tended to concentrate near the sources of its principal raw materials. In more recent years, with increased detergent usage, more emphasis is given to locations near distribution centers when new sites are considered. Although production establishments are located throughout the Nation, about half of the industry's production originates in the North Central region of the United States.

Increases in labor productivity are frequently related to increases in the stock of capital. Over the period of this study, new capital expenditures per employee in the soaps and detergents industry increased at an average annual rate of 10 percent, compared with 7.8 percent for all manufacturing. Moreover, the levels were substantially above the average for all manufacturing in almost every year. By 1976, capital expenditures per employee were 82 percent higher than the manufacturing average ($4,191, compared with $2,300). About three-fourths of the expenditures have been for new machinery and equipment, the same as for all manufacturing.

Technology changes

Soap has always been made by combining the basic ingredients, fat and alkali. The early American commercial soapmakers made soap outdoors in large iron kettles over an open fire, according to a uniform formula. The kettle method of soapmaking was used until 1940 when a major improvement was achieved in soap production technology. A continuous process was perfected which reduced soapmaking time from about a week to less than a day.[8] Today, the continuous process is dominant, although the "kettle" process is still used in some establishments.

Soap reacts with the minerals in hard water to form lime soap, which sometimes appears as a white scum in the wash water. Synthetic detergents, however, do not react this way. The term detergent usually refers to a product, which for heavy-duty laundry use, generally contains an organic surface active agent (surfactant), an inorganic builder, and various other ingredients. Also, "detergent" is sometimes used to denote the organic surfactant.[9]

German scientists are credited with developing the first synthetic detergents during World War I.[10] Synthetic detergents were introduced into the United States during the early 1930's. The first synthetic detergents performed well in hard water; however, their cleaning ability was limited in laundry usage. In the 1940's, the discovery and development of phosphates, primarily sodium tripolyphosphate, led to the first "built" synthetic detergents which not only performed well in hard water, but provided the cleaning power necessary for laundry use.[11] By 1958, soap for many centuries the chief cleansing agent for household laundry and dishwashing use, had been largely replaced by synthetic detergents.

Detergents reformulated. Developments over the past 15 to 20 years have resulted in many changes in product composition. Because of environmental concerns, detergent products have been and are still being reformulated. One of the first changes in detergent composition occurred in 1964–65 involving the replacement of the organic surfactant with a type which degrades rapidly in the environment.[12] Specifically, "hard" branched-chain alkylbenzenesulfonate (ABS) was replaced by "soft" biodegradable linear alkylbenzenesulfonate (LAS). LAS is still a major detergent ingredient.

By the late 1960's, the focus of environmental concern shifted to phosphate levels in detergent products because of the controversy over the effect of phosphates upon rivers, streams, fish, and other wildlife. Legislation restricting phosphate levels in detergents was introduced, including a total ban on phosphate in detergents in several States. To maintain detergent performance with reduced phosphate levels, surfactant levels are generally increased. Also, the use of surfactants, which are even less sensitive to water hardness than LAS, helps to maintain cleaning performance. For this reason, surfactants based on long-chain alcohols have become more popular.

These detergent formulation changes which occurred in the mid- and late 1960's coincided with years in which productivity grew substantially less than the industry long-term average. Also, exceptionally large annual increases in nonproduction workers occurred which suggests that the industry, in response to the environmental concerns, expanded its research efforts into the development of environmentally more acceptable products.

Although sodium tripolyphosphate is still the leading detergent builder, new builders are beginning to appear and are currently used as phosphate substitutes. These include sodium carbonate, sodium silicate, and various surfactant blends. Other possible phosphate replacements are being developed and tested, but none of these materials has proved to be a total replacement on a one-to-one basis.

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Production processes improved. By 1958, virtually all of the basic equipment currently used in soap and detergent making had been developed. Most of the improvements which became available later were technological refinements of the basic equipment and production processes. However, some notable improvements have been introduced.

One of the major processes in the manufacture of synthetic surfactants is sulfonation. In this process, a nonsurface-active hydrocarbon (alkylbenzene, for instance) is converted into surface-active alkylbenzenesulfonic acid, and subsequently neutralized to a salt. Oleum is the sulfonating agent.[14] In the mid–1950's, an innovation was developed which permitted the industry to convert batch sulfonation into a continuous process. With the continuous oleum process, a high-quality, uniform product could be obtained which met the important production criteria, principally light color and low free oil (unconverted hydrocarbon) in the final sulfonation product. Time saving is another advantage; the continuous sulfonation process is completed in a matter of minutes, whereas the batch process requires 6 to 10 hours.[15]

In the mid–1960's, a further improvement was introduced in the continuous sulfonation process involving a change from oleum to sulfur trioxide (SO_3) gas, mixed with air, as the sulfonating agent. The industry-wide trend towards the use of continuous SO_3 has occurred mainly because former sulfonating agents, such as oleum, have higher chemical costs, and present disposal problems of spent sulfuric acid. Also, some of the newer types of raw materials mentioned earlier cannot be processed efficiently except with SO_3. This process provides a high-quality product by minimizing product degradation due to the short reaction time, reducing costs, and realizing labor savings in the handling of the acid disposal product.[16]

Continuous sulfonation processes with automatic controls minimize labor requirements. An entire continuous sulfonation plant can be operated with one operator, rather than the two or three operators needed in the batch and semi-continuous plants.[17]

Packaging operations in the industry have long used automatic equipment. However, some technological modifications have been introduced. For example, machines have been developed to handle larger powder packs and at the same time are capable of erecting cartons, and filling and closing them at higher speeds. For liquids, machines have also been introduced that can achieve higher filling speeds.

High-speed soap bar production. Changes have also been made in soap bar finishing operations.[18] Although continuous soap production lines have been in operation for many years, the need for faster production rates and the development of more complex shapes of bar soaps spurred improvements over the past 15 years. Extensive changes have occurred in the design of the equipment and the line configurations.

New high-speed lines for production of simple or uniform type bar soap formulas have broken the traditional line speed barrier of 150–200 bars per minute. With the high-speed lines, 200–300 soap bars can be produced each minute. Modern specialty lines are available which provide flexible processing capability. A variety of toilet bar formulations such as synthetic detergent bars, soap-synthetic bars, and translucent soaps can now be produced at reasonable speeds. New high-speed stamping machines have also been developed which can produce up to 400 bars per minute either banded or bandless. In addition, refrigerated stamping dies have become standard in the industry. They serve to improve product appearance, to lessen die-fouling, and to improve production rates.

New developments have also been made in the machinery that is widely used to package bar soaps. These developments complement the development of the high-speed finishing lines and have been directed primarily toward wrappers, cartoners, and bar soap transfer units. This new equipment has the capability of attaining higher speeds and has the flexibility of handling various shapes of bar soap.[19] In the past, bar soap transfer units were limited to maximum speeds of 200 bars a minute. In the last 4 to 5 years, the speed has been increased. Wrappers, cartoners, and bar soap transfer units are being introduced that are capable of average production speeds of up to 300 bars a minute for the mass-produced soaps.

Computer technology has made possible the centralized instrumentation of the production processes, although the industry has always been highly mechanized. Computers are increasingly being used for jobs such as inventory control, flow and measurement of raw materials, formula calculations, and in mixing operations to assure uniformity of soap and detergent mixes. Marketing analysis can more easily be accomplished with computer-based information systems. The use of computer processing provides information that can be used to better allocate the time required for many activities, resulting in improved utilization of labor.

Shortrun changes in productivity in the soaps and detergents industry will continue to be affected by changes in demand. Over the longrun, the high levels of capital investment per employee should help to keep industry productivity gains in line with the average for all manufacturing.

Substantial demand for virtually all of the products produced by the industry should continue into the immediate future. The output of dishwasher detergents should especially show growth as the utilization of

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existing dishwashing machines is increased, and the ownership of home dishwashers is expanded. The number of washing machines in U.S. households is also expected to increase, thus generating additional growth for the soaps and detergents industry.

[1] The soap and other detergents industry comprises establishments primarily engaged in manufacturing soap, synthetic organic detergents, inorganic alkaline detergents, or any combination thereof, and refined glycerine from vegetable and animal fats and oils. The industry is designated as number 2841 in the Office of Management and Budget's *Standard Industrial Classification Manual (SIC), 1972 edition.* Data prior to 1958 are not comparable. All average annual rates of change are based on the linear least squares trends of the logarithms of the index numbers. Extensions of the indexes will appear in the annual BLS Bulletin, *Productivity Indexes for Selected Industries.* A technical note describing the methods used to develop the indexes is available from the Division of Industry Productivity Studies.

[2] *U.S. Industrial Outlook,* various issues.

[3] *Industrial Outlook,* 1970, p. 181.

[4] Dieter H. Von Hennig, "The Role of Detergent Alcohols in the Soap and Detergents Industry, A Bicentennial Update," Shell Chemical Company, at Chemical Industry Association, Inc. Workshop Meeting, Absecon, New Jersey, June 14, 1976.

[5] Richard C. Davis, "Washer-detergent-textile Interactions," *Hydrocarbon Processing,* March 1975, pp. 90–92.

[6] Richard B. Carnes, "Laundry and cleaning services pressed to post productivity gains," *Monthly Labor Review,* February 1978; and "1976 Statistical and Marketing Report," *Merchandising,* March 1976, pp. 38–42.

[7] Bureau of Labor Statistics, unpublished data for 1970–85, National Industry Occupational Matrix.

[8] "About Soap," *Procter and Gamble Service Bulletin,* Procter and Gamble, Cincinnati, Ohio.

[9] Based on information provided by Dr. Arno Cahn, Development Director, Household Products, Lever Brothers Co.

[10] "Some Facts About Procter and Gamble Detergents," *Procter and Gamble Information Bulletin.*

[11] Anne L. Lyng, "Detergents in Review," *Detergents—in Depth,* a symposium sponsored by The Soap and Detergent Association, Washington, D.C., Mar. 28–29, 1974, pp. 2–7.

[12] T. E. Brenner, "Soaps and Detergents: North American Trends," The Soap and Detergent Association, in Proceedings—World Conference on Soaps and Detergents, Oct. 9–15, 1977, Montreux, Switzerland, pp. 5–8. Reprinted in *Journal of the American Oil Chemists' Society,* January 1978. Also see, O. Carl Kerfoot and H. R. Flammer, "Synthetic Detergents: Basics," *Hydrocarbon Processing,* March 1975, pp. 74–78.

[13] Brenner, "Soaps and Detergents."

[14] Based on information provided by Dr. Arno Cahn, Development Director, Household Products, Lever Brothers Co.

[15] *Oleum Sulfonation Process Equipment,* The Chemithon Corp., Seattle, Washington, 1968. Also conversation with respresentative of The Chemithon Corporation.

[16] *Sulphur Trioxide Detergent Process Equipment,* The Chemithon Corp. Ibid.

[17] *Oleum Sulfonation Process Equipment and Sulphur Trioxide Detergent Process Equipment.* Ibid.

[18] A. B. Herrick, "Bar Soap Finishing—New Trends in Soap Processing Line Design and Layouts," Armour-Dial Company, in Proceedings—World Conference on Soaps and Detergents, Oct. 9–15, 1977, Montreux, Switzerland. Reprinted in *Journal of the American Oil Chemists' Society,* January 1978, pp. 147–50.

[19] L. Spitz, "Bar Soap Packaging," ACMA S.p.A., in Proceedings—World Conference on Soaps and Detergents, Oct. 9–15, 1977, Montreux, Switzerland. Reprinted in *Journal of the American Oil Chemists' Society,* January 1978, pp. 151–55.

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Measuring Productivity in Government

Federal, State, and Local

JEROME A. MARK

As a result of the growth of government, which now employs one out of every six members of the workforce, and public concern over the rising costs of government, the need to develop measures of productivity for public agencies has become increasingly important. However, the concepts underlying productivity measurement are so complex, that experts do not share a common perception of the field; rather, they define the nature and purpose of productivity measures in a number of ways, particularly with regard to the public sector. The public sector literature variously defines productivity measurement as measurement of efficiency, effectiveness, cost reduction, input-output, management improvement, performance, methods improvement, work standards, and program evaluation.

Efforts to evaluate productivity can be grouped into three broad areas; programs employ either efficiency type measures, operational type measures, or effectiveness type measures. Efficiency type measures compare the inputs or resources an organization uses with the final goods or services it produces. This measurement approach does not, however, determine whether these products should be produced or relate them to some desired goal.

Where efficiency type measures assess the productivity of a given activity by relating that activity to its result or some kind of finished product, work measurement or operational type measures are mainly concerned with the activity itself. As John P. Ross and Jesse Burkhead point out, "work measures examine the work activity itself rather than its results and are usually measured in terms of activity per unit of time."[1] Work measures evaluate intermediate activity by assessing resource requirements under a given technology or set of conditions; in contrast, productivity measures relate inputs to final products.

Unlike efficiency or operational type measures, effectiveness type measures quantify a program's impact on society and determine whether that program makes optimum use of inputs or resources to achieve its goals. The output indicator for this approach to measurement is the effect that an activity has on a portion of the public. The thrust of measurement changes from a comparison between the goods and services that a program or activity produces and the inputs used, to a study of the public that consumes those goods and services.

The principal differences between the three productivity evaluation systems lie in the definition and measurement of outputs. Bradford, Malt, and Oates have classified efficiency type measures as measures of "direct outputs" and effectiveness type measures as measures of "consequences."[2] In many cases, however, this distinction is more apparent than real.

Although there is a substantial amount of confusion about the specific meaning of "productivity," it seems clear that all of these performance measures help public sector managers make decisions. The degree of difference between efficiency and effectiveness measures is greater in the public sector than in the private sector. In the private sector, competition and market forces encourage businesses to operate efficiently and effectively so that they can provide the goods the public demands at prices consumers are willing to pay. Because market forces and competition do not affect the public sector, the relationship between efficiency and effectiveness becomes more tenuous. For this reason, it is far more important to separate these two measures in analyses of the public sector than in analyses of the private sector.

Each of the three kinds of measurement systems—efficiency, work, and effectiveness—is important in its own right, and each plays a role in evaluating productivity. However, much of the re-

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[1] John P. Ross and Jesse Burkhead, *Productivity in the Local Government Sector* (Lexington, MA: Lexington Books, 1974), 14.

[2] D.F. Bradford, R.A. Malt, and W.E. Oates, "The Rising Cost of Local Public Services: Some Evidence and Reflections," *National Tax Journal,* XXII (June 1969) 185-202.

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search on productivity focuses on efficiency type measures and these are the measures which this paper principally addresses.

Productivity Measurement at the Federal Level

For several years, the principal effort to measure the productivity of agencies in the federal government has been the Bureau of Labor Statistics' program to develop labor productivity indexes for all government agencies with 200 or more employees. This program was undertaken first in conjunction with the General Accounting Office, the Office of Management and Budget, and the Civil Service Commission, later with the National Center for Productivity and Quality of Working Life, and is currently administered with the Office of Personnel Management.[3] The program currently obtains data and develops measures for approximately 350 agencies representing about sixty-five percent of federal employment. Table 1 shows the growth in the coverage of the project over the years.

The measures developed are indexes of output per unit of labor input (generally, employee-year) and the agency measures are grouped into functional categories that have common characteristics. Table 2 shows the functional categories for which measures are derived and the associated average annual rates of change for productivity and related series.

The productivity indexes developed compare the current output-input relationship with that of a previous reference period, in this case fiscal year 1967, and the measures reflect the changes which have taken place in labor input per unit of output regardless of the mission of the organization.

Where it is possible, the relevant concept of output for a government agency is its final product—that is, what the given organization produces for use by the public or other government agencies. The output data included in the overall sample used for this study is final from the perspective of both the agency itself and the functional groupings in which these agencies are classified.

However, since one federal agency may consume all or some of the outputs of another federal agency to produce its own final outputs, all output indicators are not final from the perspective of the entire federal government. Therefore, the overall statistics presented in the study do not represent "federal government productivity," but rather the average of the productivity changes of the measured federal organizations included in the sample.[4]

It is particularly important to understand the meaning of these statistics in order to use this data for improving the measurement of general government output in the National Income and Product accounts. Real gross product originating in general government at present is measured by moving the base year compensation of government employees by changes in employment adjusted for shifts in grade structure. As a result, the implied productivity change for this measure is biased toward zero reflecting only the impact of the change in grade structure of federal employees. Since real gross product is a net measure, it is necessary to net out intermediate output in order to use it in the development of improved GNP measures.[5]

[3] For descriptions of the work on this project and the presentation of results, see U.S. Congress, Joint Economic Committee, *Measuring and Enhancing Productivity in the Federal Sector* (Washington, D.C.: U.S. Government Printing Office, 1972); Jerome A. Mark and Charles W. Ardolini, "Developments in Measuring Productivity in the Federal Sector," *Proceedings of the Business and Economics Section of the American Statistical Association* (Washington, D.C., 1974) 236-45; Joint Financial Management Improvement Program, *Productivity Programs in the Federal Government* (Washington, D.C.: U.S. Government Printing Office, 1975).

[4] Mark and Ardolini, "Developments in Measuring Productivity."

[5] For a discussion of the problems of using this data in the national income and product accounts, see Charles A. Waite and Allan D. Searle, "Current Efforts to Measure Productivity in the Public Sector: How Adequate for the National Accounts," and Jerome A. Mark, "Comments on Searle and Waite," in *New Developments in Productivity Measurement and Analysis; Studies in Income and Wealth,* Edited by John W. Kendrick and Beatrice N. Vaccara (Chicago: University of Chicago Press, 1980).

	Fiscal Year							
	1971	1972	1973	1974	1975	1976	1977	1978
Agencies	17	45	46	49	51	51	50	50
Organizational Units	114	187	200	245	279	307	319	347
Output Indicators	948	1120	1201	1581	1747	2035	2334	2660
Civilian Employee-Years Covered (millions)	1.6	1.7	1.7	1.8	1.9	1.9	1.8	1.8
Total Civilian Employee-Years (millions)	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Employee-Years Covered as Percent of Total (millions)	54%	60%	61%	65%	66%	66%	64%	65%

Table 1: Coverage of the Federal Productivity Measurement Program

Although it would be desirable to have a net measure of federal government output and productivity, this is not possible at present. While it is possible to identify some of the measured outputs that are consumed inside the federal government, sufficient data is not available to determine the degree of internal consumption.

To determine final output indicators, the agencies and the Bureau of Labor Statistics (BLS) must identify specific units of services which are countable, fairly homogeneous over time, flexible enough to be adjusted for quality changes, and representative of the agencies' workload. In addition, since historical trends are of interest, it is important that the measures are easy to contruct from readily available records.

The indicators vary substantially. They include such diverse items as trademarks disposed, tanks repaired, weather observations made, square feet of buildings cleaned, electrical power generated, and deportable aliens located. The output volumes range from several hundred units completed per year (e.g. river basin studies) to billions (e.g. mail delivery items).

Employee-indexes are developed from the data each agency submits. As in all labor input measures used to develop productivity indexes, employee-years are treated as homogeneous and additive and no distinction is made between different groups of employees.

Since the productivity measure is a labor productivity series, the line item output indicators are combined with the corresponding labor input weights. These weights are constructed from the detailed output and input data provided by each participating organization.

BLS productivity indexes measure both the overall sample and also twenty-eight major functions representing relatively homogeneous groups of activities such as library services, procurement, finance and accounting, electric power production, and postal service. Although indexes for each of the 350 organizational units have also been constructed, they are not published. Rather, they are returned to each organization for its own use (e.g.to stimulate further examination of productivity changes).

MEASUREMENT PROBLEMS. There are several important problems in measuring productivity in the federal sector. Because most federal activities are service oriented, it is often difficult to define and quantify outputs; government agencies usually do not produce clearly specified physical products comparable to the goods produced by the private sector. Moreover, after the output indicators are specified, they must be in sufficient detail to represent a homogeneous group of services. If the output units represented by the output indicator are not homogeneous, and if over time the proportion changes between units that are more or less

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Functional Groupings	Output per Employee-Year	Output	Employee Years	Compensation Per Employee Year	Unit Labor Cost
Total	1.4	1.3	-0.1	8.7	7.2
Audit of Operations	2.5	-1.2	-3.6	7.2	4.6
Buildings & Grounds Maintenance	2.5	0.6	-1.9	9.5	6.8
Communications*	10.1	9.8	-0.2	6.8	-3.0
Education & Training†	0.9	-1.2	-2.0	8.1	7.1
Electric Power Production & Distribution	0.3	7.9	7.6	8.1	7.8
Equipment Maintenance†	0.4	-3.2	-3.6	7.8	7.4
Finance & Accounting	2.4	0.2	-2.1	7.7	5.2
General Support Services	3.9	6.0	2.1	7.3	3.3
Information Services	0.3	1.7	1.5	5.7	5.5
Legal & Judicial Activities	-0.3	3.9	4.2	5.6	5.9
Library Services	5.3	8.6	3.2	8.4	3.0
Loans & Grants	4.2	5.1	0.9	7.9	3.6
Medical Services	-0.1	1.9	2.0	7.9	8.0
Military Base Services	-0.4	-4.6	-4.2	7.4	7.9
Natural Resources & Environment Management	1.3	1.0	-0.3	7.0	5.6
Personnel Investigations	3.6	12.6	8.7	6.6	2.9
Personnel Management	1.8	6.6	4.7	5.4	3.5
Postal Service	1.3	0.8	-0.4	10.2	8.8
Printing & Duplication	-1.5	-3.5	-2.0	9.4	11.0
Procurement	2.0	-0.9	-2.9	5.4	3.3
Records Management	3.1	-1.4	-4.4	8.3	5.0
Regulation-Compliance & Enforcement	2.0	5.0	3.0	6.9	4.9
Regulation-Rulemaking & Licensing	2.6	4.6	2.0	6.7	4.0
Social Services & Benefits	2.8	7.5	4.6	7.0	4.1
Specialized Manufacturing	1.9	-0.7	-2.6	8.5	6.5
Supply & Inventory Control	2.0	-4.8	-6.7	7.4	5.3
Traffic Management**	1.3	-3.4	-4.6	5.7	4.4
Transportation	2.6	3.4	0.8	8.5	5.7

Source: Bureau of Labor Statistics, U.S. Department of Labor. Average annual percent change based on linear least squares trend of the logarithms of the index numbers. * is fiscal year 1973-1978. † is fiscal year 1968-1978. ** is fiscal year 1972-1978.

Table 2: Functional and summary average annual rates of change in output per employee-year and related data for the measured portion of the federal civilian government, fiscal years 1967-1978

labor intensive, the resultant output per employee-year measure will reflect not only the change in productivity—the change in the amount of labor required to produce the base year composite—but also shifts in the types of output.

Another related problem is that some reported outputs do not reflect changes in output quality. Adjustments for changes in output quality are necessary in order to appropriately measure the changes in resources used per unit of similar type good or service. If a reduction in labor requirements per unit of output results from a change in the dimensions of the output or in the quality of the service, then the resultant measure does not reflect productivity improvement.

For purposes of labor productivity measurement, changes in output quality, which reflect an altered production process with different base period labor requirements, can be considered as basic changes in the output. Similarly, changes in output characteristics, which affect the value of the output to the user but not an altered production process or different base period labor requirements, do not require special treatment.

The main remedy for these difficulties is to collect more detailed data. For example, initially the only output indicator used to assess the productivity of the Postal Service was the number of pieces of mail handled. By examining other Postal Service data, BLS learned that output indicators covering various types of mail (e.g. registered and first class) and other services (e.g. money orders) were available. The measure for the Postal Service is now based on this detailed data and takes into account shifts in the importance of the different types of mail services, all of which require different levels of unit labor.

Although the use of this additional product detail has improved the accuracy of the measure for this function, opportunities for further improvement remain. For example, at the present time the measure reflects shifts between the less labor intensive deliveries to large office buildings which have centralized mail distribution facilities, and the more labor intensive deliveries to scattered private, suburban residences, as well as productivity changes in these component activities. It would be desirable to adjust the measures for these shifts.

BLS has sought, and in some cases obtained, detailed output indicators, but in many cases the reported measures only summarize an agency's activities. For example, the indicators record the total number of weapons overhauled rather than breaking this figure down by type of weapon and specifying type of repair. In order to ensure that units of reported output were homogeneous, BLS asked each participating agency to specify typical maximum and minimum amounts of time required to produce one output unit. A narrow range indicated that the labor requirements for each unit of output were relatively homogeneous within a given year and that the effects of a shift in output mix would be minimal. Conversely, a wide range indicated that the units measuring output were not standard and thus could not reliably reflect changes in a shift in output mix. Most outputs had a relatively narrow range; however, a limited number of output indicators showing wide ranges had to be dropped from the study.

Outputs having long production cycles (i.e. requiring many months or in some cases, years to complete) also present difficult measurement problems. Quantifying such outputs only in the year they are completed produces output measures that are inconsistent with the associated factor input. When production time extended beyond one year, estimates of the proportion of long term outputs produced in each year were made.

Closely related to the problem of quantifying output are the difficulties that emerge when the federal government contracts out work. In these cases, the final output measure for a govern-

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ment agency may reflect the activities of not only the agency's employees, but also its private contractors. It is important to determine which output is exclusively associated with government employees, because the input measure should be limited to them. For example, the Employment and Training Administration of the Department of Labor administers contractor-operated job training programs. Analyses of the productivity of these programs did not directly use the outputs of the contractors since it could not be established that the output of the federal employees was proportional to the results or the activities of the contractors. The project attempted to compensate for this problem.

Departmental reorganizations also present difficulties in obtaining consistent output and employee-year data. Whenever a reorganization occurred, respondents were asked to submit consistent data on the basis of either the new or the old organizational structure. Within the Department of Labor's Employment and Training Administration, for example, the offices overseeing training, employment, and unemployment compensation services were reorganized several times during the fiscal years 1967-1978. BLS has developed a separate measure for the unemployment insurance activities, but since the training and employment counseling services are so closely related and their records are so intertwined, it was considered more appropriate to construct a combined measure for these activities. Using budget and other documents, BLS developed indexes based on the current organizational structure for the fiscal years 1967-1978.

CURRENT EFFORTS. BLS is attempting to expand the program's coverage of the federal sector. It is believed that the sample's coverage can be expanded from the sixty-five percent of federal employees it now includes to a maximum of perhaps eighty-five percent of federal employees. Much work needs to be done before measures can ever be developed for areas such as the research activities in the National Aeronautical and Space Administration and the National Bureau of Standards.

Therefore, BLS concentrates on improving the output indicators currently reported. This process involves developing indicators that more accurately represent the results of an agency's activities; these improved measures will use more clearly defined and detailed product information than some of the indicators presently in use.

On the input side, BLS devotes some attention to exploring ways of accounting for changes in the characteristics of the federal work force. In the present set of measures, all employee-years are treated as homogeneous and additive. It would be desirable to learn how shifts in the composition of the work force effect changes in output per unit of labor unit input.

In addition to the work of BLS and the Office of Personnel Management (OPM), various federal agencies have undertaken other activities generally reflecting efficiency-type measures.

OTHER EFFORTS AT FEDERAL LEVEL. While BLS conducts the annual productivity data call to construct measures for the overall federal government and the functional categories, participating federal agencies conduct their own research efforts to develop measurement systems. These measurement systems are developed internally but often are technically supported by BLS or aided by outside contractors. As the systems become operational, BLS will review the methods they use and may incorporate their results in the overall federal statistics. The examples that follow demonstrate the approaches that are being developed to overcome conceptual problems in productivity measurement.

The Naval Systems Command has enlisted BLS support to develop meaningful measures of productivity for its ship overhaul activities. Ship overhaul presents two significant measurement problems. This activity involves outputs with a long production cycle time; it sometimes takes more than eighteen months to retrofit a ship. Recording these outputs only in the year they are completed produces an output measure that is inconsistent with the associated input measure. In addition, the customized nature of the output precludes the development of a standard unit of output that remains homogeneous over time.

These problems can be addressed by estimating the proportion of long-term output produced in each year or by breaking the final outputs down into component parts, each of which is completed within a measurement period. The thrust of this productivity measurement program is to analyze ship overhaul in terms of repairs to the ship's major systems such as its hull, armament, and propulsion and electrical systems. Within each of the systems, the navy has selected sample indicators that reflect the output of the system and are homogeneous over time. Data is now being collected and the final results should yield an accurate and useful measure of productivity in ship overhauling.

A research project in the area of hospital care is underway at the Veteran's Administration. Traditionally, productivity measurement has been weak in this area because the output indicators generally used in these activities (beds occupied, patient-days, or patients treated) have severe limitations. The measures which result from the use of these indicators do not reflect the varying resource requirements needed by type of illness (e.g. fractures versus cardiovascular diseases). The measures also contain a bias of unknown direction and magnitude because the length of stay per type of illness varies over time. A more accurate measure of productivity would distinguish between type of illness, diagnostic category, etc., and would make allowance for the fact that varying units of labor are required to treat each type of illness.

BLS staff have provided technical assistance to the Veterans Administration in its effort to portray trends in productivity more accurately. This project is part of a new integrated management information system. The purpose of the system is to provide more timely data on costs and to develop a firmer basis for estimating employment needs.[6]

Some agencies are conducting measurement activities that are designed along the lines of the Mundel hierarchy of work units.[7] This approach classifies service outputs into well-defined quantifiable units of work. The various classifications serve as a guide for tracing the production cycle from resource input to the organization's outputs or achievements. The methodology begins with time and motion studies, moves to the measurement of intermediate and final output, and ends with an attempt to measure effectiveness. While the basic model postulates eight levels of work units, it can collapse or expand to meet the needs of the organization. The Veterinary Service of the Department of Agriculture, which has the mission of ensuring that livestock herds are free of infectious diseases, uses this system to evaluate animal inspection activities. The Department of the Interior, HEW, and the Secret Service have also employed this measurement technique.

At the Department of Housing and Urban Development (HUD), a new management control system allocates regional staff. The system classifies major programs into categories depending on the activities required to complete defined outputs. Known as the operating plan system, this program planning tool permits HUD to allocate staff on the basis of workload projections. For instance, the system develops standard times required to process a housing application. Given a reasonably accurate estimate of the number of applications it will have to process in the upcoming year, HUD

[6] A recent discussion of the various approaches to productivity measurement in hospitals is provided by W. Richard Scott, "Measuring Outputs in Hospitals," in *Measurement and Interpretation of Productivity* (Washington, D.C.: National Research Council, National Academy of Sciences, 1979), 255-75.

[7] Marvin E. Mundel, *Measuring and Enhancing the Productivity of Service and Government Organizations* (Hong Kong: Asian Productivity Organization, 1975).

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can determine labor requirements for that output. The operating plan is set at the beginning of the year and each month accomplishments and staff-years utilized are compared to targeted forecasts. This permits HUD to examine staff utilization rates and re-allocate resources when unplanned disruptions occur. While the HUD program springs from detailed work measurement concepts, the system is flexible to permit data aggregation at any level of analytical need. Thus, when the system becomes fully operational, BLS will be able to derive productivity data from an automated system.

Lastly, mention must be made of OPM's experimental project in the area of administrative services. The project is designed to measure productivity of a common support service and has standardized definitions to facilitate inter and intra-agency comparisons so that managers have an adequate amount of information on which to base decisions. The project began with the function of personnel services and is now in the second year of data collection.[8] Data is being collected on outputs and inputs within the categories of staffing actions, position classification, labor relations, employee development, and general administration. In contrast to the existing Federal Productivity Measurement System, which directly collects outputs and associated inputs, OPM's measurement system employs random sampling techniques to generate weighting factors. As the pilot project proves feasible, OPM officials hope to extend it to other administrative services such as finance, procurement, and data processing.

Some federal agencies have aggressively pursued efficiency research activities and are examining indicators that may demonstrate how effectively they are meeting their mission statements. These measures go beyond the efficiency measures contained in the federal productivity data base. For the purposes of efficiency, the Drug Enforcement Agency is measuring the number of narcotics arrests forwarded for prosecution. For the purposes of effectiveness, that is, how well the agency is discharging its mission to protect society from illegal drugs, the measure may be an index of narcotics prices (i.e. rising prices indicate a declining supply) or a measure of drug-related deaths and hospitalizations.

Some agencies involved in activities such as awarding grants have been attempting to develop effectiveness measures. Where the grant is for research, as in the physical or behavioral sciences, one approach has been to have a peer group evaluate the quality of the research or to record the number of times the findings of the research are cited in professional journals. The National Science Foundation uses this approach to measure the quality of the research activities it funds.

In agencies that disburse monies, common measures of effectiveness are the percent of payments made on time, the timeliness with which lost checks are reissued, and the percent of financial reports for public use completed on time.

Within the Employment and Training Administration (ETA) of the Department of Labor, a primary function is to issue contracts for the operation of Job Corps centers. ETA measures this effort by expressing the number of trainees placed in Job Corps centers as a percent of expected slots to be filled. ETA believes this approach permits it to analyze its success in meeting expansion targets of the Job Corps program.

Some organizations attempt to combine efficiency and effectiveness into a single overall performance indicator. The Army Material Command, for example, has adopted a procedure which develops one measure for effectiveness and a separate measure for efficiency for each of the command's depots. The results of all the depots are then numerically ranked on a scale from one to fifteen. The procedure assigns one score for effectiveness and one for efficiency; the combined score represents each depot's performance. Thus, with one indicator, the Army Material Command shows both how well a mission is accomplished (effectiveness) and how completely resources are utilized (efficiency).

It seems better to keep the two types of productivity measurement systems separate. Different types of productivity measures serve different purposes. For example, assessing the amount of resources used per unit of output in order to improve resource allocation may call for an efficiency type measure. Evaluating the impact of resource use on program goals may call for an effectiveness type measure. It is doubtful that combining different types of measures into a single measure would produce satisfactory measures in most cases.

FUTURE DIRECTIONS. While BLS has extended productivity measurement to cover agencies representing two-thirds of the federal government's civilian work force, further expansion is required. In the future, however, the measurement program's rate of growth will slow because it is difficult to define and quantify the output of many of the government agencies not currently covered by the program. Research and development and policy-oriented activities, such as those in the National Institutes of Health, the State Department, and defense activities fall into this category. Innovative approaches to measurement must be developed for these activities.

BLS must continue to refine and improve existing output measures in the present measurement system. It will be necessary to modify reporting systems to provide more suitable indicators.

Moreover, as the federal establishment places increased emphasis on gauging the performance of organizations, federal agencies will have to expand and develop existing measures so that they become far more detailed. As a result, the government will begin measuring outputs that are not currently measured because, under the present reporting system, they are considered as intermediate rather than final outputs. For example, an overall productivity measure of an agency may be useful when the entire agency is reviewed. However, such a measure, which masks the performance of the agency's many bureaus, administrations, or programs fails to supply enough information to the executives directing the subactivities of the agency. They need more detailed data.

As the federal establishment places increased emphasis on gauging the performance of organizations, federal agencies will have to expand and develop existing measures so that they become far more detailed.

This need is amply demonstrated by a request to BLS from the Department of Agriculture. In the department, one of the many organizations furnishing productivity information is the Soil Conservation Service. The outputs and associated inputs for the entire Department of Agriculture are collected, processed, and returned to the service for its analysis. This measure is useful for analyzing the Department of Agriculture, but the executives of the Soil Conservation Service felt additional information would be more useful. They wished to have productivity measures for the service's many programs. BLS met this need by developing productivity measures for individual programs such as flood prevention services, snow forcasts, and soil mapping. Because the Soil Conservation Service now has its own detailed set of productivity measures, it is possible to analyze the specific programs of the service as well as the overall performance of the Department of Agriculture.

It is clear that we must adopt this type of approach in order to provide managers with meaningful data. BLS has always offered to provide technical assistance in developing measures for detailed

[8] Allan S. Udler, "An Experiment in the Personnel Office," *Civil Service Journal*, XIX (January/March 1979), 32-35.

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agency use, but unfortunately, the response from the agencies has been poor. Finer levels of measurement must be stressed and encouraged if the federal agencies are to have reasonably accurate productivity measures for use in resource allocation and budgeting.

Currently, the measurement system relates output to a single factor, labor input. Since there are as many productivity measures as there are factors of production, Some people are interested in professional employees or shifts in levels of educational attainment, the results are reflected as productivity movements and not as factor input changes. Productivity measures could be refined so that they are able to adjust for such things as the age, sex, and experience of the work force. This area of research should be considered one of the more feasible expansions of the federal productivity measurement system.

It is generally agreed that the most suitable unit of labor input measure is the number of hours worked. The current input measure, employee-years, is based on the number of hours paid. Thus, the denominator of the productivity expression includes actual hours expended to produce the output plus hours paid for sick and annual leave, overtime, and accrued leave paid at separation. This probably does not present a measurement bias if the ratio of hours worked to total hours paid is stable over time. However, in the public sector, this issue has never been analyzed. While the extent of any potential bias is thought to be minimal, this subject should be researched.

The Office of Personnel Management, which is responsible for improving the productivity of the federal government, would like to see effectiveness measures supplement the existing data base.[9] As mentioned earlier, this is a most difficult area of productivity measurement. The complexities of defining and quantifying output measures involve normative judgements and a variety of assumptions. The research literature has extensively questioned the value and availability of standards, norms, or targets.[10] Even if it is possible to develop multiple measures of effectiveness, there is no clear conceptual basis for aggregating them with an efficiency measure into an overall performance measure.[11]

An example will illustrate these problems. Suppose the focus of the productivity analysis is the Social Security Administration. For an efficiency type measure, the final output indicator is the exploring alternative measures of productivity for the federal government. The most common alternative to single factor measures is output per combined unit of labor and capital. There has been a great deal of research on multifactor productivity estimates, but these efforts have been limited to analyses of the private sector. Without listing every problem inherent in the development of capital estimates, it is necessary to discuss a few difficulties that make the federal government unique when considered from the perspective of multifactor analysis.

The common form of the capital input estimate in multifactor productivity measurement is a capital stock measure. However, the government's current accounting system precludes the development of such a measure because the system charges purchases of equipment and structures in the year of acquisition. Thus, there is no convenient method for estimating the value of the capital stock available for the production of goods and services. For example, a vehicle acquired for a motor pool fleet is expensed in the year it is purchased. That vehicle has a useful life of several years and will be contributing a flow of capital services over the period of time it is in use. However, there is now no method of measuring the depreciated value of the vehicle in any year after the year of acquisition. Thus, it is necessary to introduce a system for fixing the value of capital equipment and structures before beginning to research multifactor productivity in the federal government.

An official of the Department of the Treasury has suggested the Government Financial Operations unit within the Treasury Department, a heavily computerized organization, as a possible candidate for a multifactor study. Perhaps some initial pilot studies will provide insights on developing a government-wide framework for extending productivity measures beyond comparisons of output per unit of labor input.

New ways of measuring labor input in the present system can also be explored. Current methodology considers labor input as homogeneous and additive; that is, an hour's worth of work performed by any general schedule employee regardless of his position, expertise, or experience, is weighted equally in the measure. This procedure, therefore, does not take into account the composition of the work force. Furthermore, as changes occur in the composition of labor, such as changes in the ratio of professional to non-number of checks disbursed. For purposes of effectiveness type measures, however, the choice of the proper indicator is not as obvious. The manager of the program might evaluate effectiveness by measuring the percent of the number of recipients who receive their checks on the first of the month. The political scientist or welfare economist may define effectiveness as the degree to which the income of the population served is above or below the poverty line. Thus, various disciplines would select different measures of effectiveness. In addition, the feasibility of combining the measures of effectiveness and efficiency into a meaningful overall measure of performance remains questionable.

The work which some federal agencies have carried out on effectiveness measurement is still in the experimentation stage. Much research remains to be done on the standards against which effectiveness can be measured and on possible techniques for data collection. The disciplines concerned with public sector productivity face the challenge of developing models for measuring effectiveness which accurately convey to both the public and policy planners the degree to which a public sector organization is accomplishing its goals.

Productivity Measurement at the State and Local Level

Compared with our knowledge of measurement in the federal government, we know very little about state and local government productivity measurement. The diversity and multiplicity of state and local governments and the absence of a continuing productivity information system makes it difficult to assess their productivity. The knowledge we have comes from three sources: local government surveys, academic studies, and work by the federal government on state and local government enterprise funds.

Most surveys of state and local government have concluded that the majority of governments collect and use efficiency-type productivity measures, although in many cases the measures are limited to a small group of activities. These measures are important for budgeting, auditing, review, and daily operations. A 1976 survey of local government found that about sixty-five percent of the cities and fifty percent of the counties regularly used efficiency measures at some stage of their operations.[12] More recent surveys in North Carolina and the Denver Metropolitan area also uncovered

[9] See OPM memorandum for heads of executive departments and agencies, "Federal Productivity Measurement Project: Fiscal Year 1979 Instruction Package," dated January 21, 1980.

[10] Harry P. Hatry, "The Status of Productivity in the Public Sector," *Public Administration Review*, XXXVIII (January/February 1978), 28.

[11] Jesse Burkhead and Patrick J. Hennigan, "Productivity Analysis: A Search for Definition and Order," *Public Administration Review*, XXXVIII (January/February 1978), 34.

[12] Rackham Fukhuhara, *The Status of Local Government Productivity* (Washington, D.C.: The International City Management Association, 1977).

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frequent but uneven use of efficiency measures.[13] On the other hand, a 1976 examination of budget documents of 247 cities and counties found that only ten percent contained any efficiency measures.[14] Many local governments use efficiency measures but do not include them in their budget documents.

Information on state use of efficiency measures is even more limited than that on local government. A survey of state budget documents and statistical reports in 1975 found mixed use of efficiency-type measures.[15] In fields such as corrections and education, about one-third of the states included atleast one efficiency-type measure in their budgets. These included such measures as "dollar cost of caring for inmate per inmate day" and "number of offenders per parole officer." For functions such as tourism and licensing, less than ten percent of the states included any efficiency-type measures in their budgets.

Several conclusions emerge from these surveys of state and local government use of efficiency-type measures. First of all, larger jurisdictions are more likely to develop and use efficiency-type measures than smaller jurisdictions. Secondly, the use of efficiency-type measures is very uneven from service area to service area. Thirdly, service areas subsidized or regulated by the federal government are more likely to have efficiency-type measures than other areas. In addition, services with tangible outputs, such as solid waste collection, are more likely to be measured than those with intangible outputs, such as general management. Two other conclusions emerge from these surveys which bear mentioning. State and local government documents include more effectiveness-type measures than efficiency-type measures. Also, state and local governments are increasingly interested in the development of engineered work standards. Although they can be a useful tool in increasing productivity, engineered work standards do *not* measure productivity themselves; rather, they measure normal, optimal, expected, or other amounts of time required to perform individual tasks.

Cost measures calculated by state and local government do not assess productivity either. Changes in unit costs, such as "cost per student" reflect factor price changes, as well as changes in resources used.

Over the past decade, several members of the academic community have prepared state and local government productivity indexes. For the most part, these indexes have been parts of larger research issues, such as Robert D. Reischauer's projections of state and local government cost and revenue.[16]

These studies have taken one of two approaches. One approach has been to compute a cost per unit of service such as "cost per pupil day" in the case of education and infer changes in productivity from changes in unit costs over time.[17] The other approach has been to specify unit cost as an independent variable and identify changes in productivity (and quality) through the residual term.[18]

There are a number of problems with the academic research. For most service areas, researchers have had to use "persons served" or "persons elegible for service" as the indicator of output. For example, in public safety, the "population at risk" is often used as the output measure. Such measures, unfortunately, do not define or distinguish the number of people served or the type of service provided. In these measures, a shift in population could appear incorrectly as a change in productivity.

The availability of data has dictated the selection of outputs, and aggregate data on state and local government operations is not generally available. Data that is collected nationally, such as crime rates, does not lend itself to productivity calculations, and data which would be useful for output measurement, such as tons of solid waste collected, is not tabulated nationally.

Output data is available for state and local government Enterprise Funds, which account for about seven percent of all state and local government expenditures. Government services included in Enterprise Funds are: toll highways, water transport, airports, liquor stores, parking, off-track betting, lotteries, transit and water supply systems, gas and electical utilities, housing and urban renewal, and sewerage. Enterprise Funds form the only area where the federal government calculates state and local government productivity on a continuing basis. These services are managed like private businesses; they sell goods and services, make profits or losses, and pay taxes. Changes in Enterprise Fund activity are reflected in the BLS quarterly index of private sector productivity.

The process used in calculating Enterprise Fund outputs is to take total sales, add any government subsidies, and deflate to obtain the outputs. These statistics are drawn from the annual census of governments and are supplemented with trade association information and other data. The labor data is also taken from the same sources. Employment data is taken from the current employment survey by BLS.

State and local government Enterprise Funds are currently included in private sector non-farm business productivity calculations. It would be possible to identify Enterprise Funds separately, by service, and calculate a specific state and local government Enterprise Fund productivity index if that were desired.

CURRENT EFFORTS. Research on state and local government productivity measurement has decreased in recent years, partly due to the termination of the National Center on Productivity and Quality of Working Life. Financial support from the National Science Foundation and the Department of Housing and Urban Development has also decreased. However, BLS has launched a new effort. Its investigation assesses the possibility of calculating state and local government productivity indexes and gross output measures. The effort is similar to those underway in individual industries and the federal government. The services focused on include state liquor stores, electric power distribution, mass transit, elementary and secondary education, and hospitals and roads.

In each case, researchers examine prior studies, specify a series of outputs, identify quality or service factors that must be adjusted for, survey the available data, identify labor input data, and document the results. If researchers can not calculate an index from existing data, they suggest procedures to accumulate data and estimate resources.

The project has been underway for only a short time, and has focused almost entirely on the Enterprise Funds, but it has yielded several tentative findings. Some service areas, such as mass transit and public power have been extensively researched and there is general agreement about methods of measurement for these areas. In other service areas, such as liquor stores, there has been little research on productivity techniques, but evidently measurement of these activities does not present serious problems. In other areas, such as education, there is considerable research but little agreement about productivity measurement. Also, some of the data necessary for computing a state and local productivity index is readily available from federal sources (e.g. public power statistics); other data appears to be available from the states (e.g. liquor stores); and some data is not currently available but the Department of

[13] Research Triangle Institute, *Comparative Performance Measures for Municipal Services* (Raleigh, N.C.: December 1978); Denver Regional Council of Governments, *A Demonstration of Comparative Productivity Measurement*, (Denver: Regional Council of Governments, 1978).

[14] Hatry, "The Status of Productivity in the Public Sector," 29.

[15] Urban Institute, *The Status of Productivity Measurement in State Government: An Initial Examination*, (Washington, D.C.: The Urban Institute, 1975).

[16] Robert D. Reishauer in Charles L. Schultze, *Setting National Priorities: The 1972 Budget* (Washington, D.C.: The Brookings Institution, 1971).

[17] Bradford, Malt, and Oates, "The Rising Cost of Local Public Services."

[18] Ross and Burkhead, *Productivity in the Local Government Sector.*

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Transportation is now devising a system that should eventually provide the needed information. Finally, the study indicates that each service area must be examined in depth. Very little knowledge or data can be transferred from one service area to another.

As far as the federal government is concerned, the climate is not bright for new initiatives in this area. The National Productivity Council recently concluded that the federal government should not make a major investment in the measurement of state and local government productivity:

> The costs and relative benefits of a federal effort in this area compared to other forms of federal support do not warrant a major federal investment at this time. More analysis of the conceptual problems and approaches should be made. In the meantime, federal agencies should be encouraged to continue their individual efforts to support state and local government productivity measurement and, where possible within their own budget priorities, expand such efforts.[19]

FUTURE DIRECTIONS. One thrust of the BLS study of state and local government productivity measurement is to identify those areas needing additional research. The most difficult issue, of course, is output measurement, particularly in areas, such as education, where there is a large body of research but little agreement on measurement approaches, or parks and recreation, where there is little research and no agreement on productivity approaches. Most state and local govenment services fall into these two categories.

Related to the quantity of outputs is the quality and level of service. The need to account for quality differences when calculating state and local productivity has been discussed at length. There has been little research on the impact quality variations have on the production costs of specific state and local government services. Properly adjusting for changes requires a thorough understanding of these relationships.

Data availability is an important research issue in its own right. Given today's fiscal restraints, it is almost impossible to collect vast amounts of data. In some cases, it should be possible to use existing data to compute state and local government productivity indexes. In other instances, it may be necessary to establish new data collection procedures. For each service area, it is necessary to determine the most cost-effective way to fill the gaps in existing data.

[19] National Productivity Council, *Federal Actions to Support State and Local Government Productivity Improvement* (Washington, D.C.: National Productivity Council, 1979), vii.

Information on the quantity of labor hours is necessary for calculations of state and local government labor productivity. Reports on the state and local government work force in current surveys, such as the Census of Governments, Current Population Survey, and Unemployment Insurance Report, have major limitations. A systematic examination of the current situation and the opportunities for modification is needed. This examination should assess methods of indicating shifts in the composition of the work force.

For most state and local government operations, labor is the most important resource, and in some cases, it accounts for eighty-five to ninety percent of operating costs. Thus, it is only appropriate that state and local government productivity programs start by focusing on labor productivity. However, for some services such as streets, power utilities, and water and sewer systems, where capital input is a substantial factor, an additional measure of multifactor productivity including labor and capital is desirable. By addressing a limited number of state and local government service areas, it should be possible to develop a better appreciation for the problems and opportunities in developing efficiency-based productivity indexes. BLS has used this approach for its industry work and its state and local government work.

Conclusion

Although public sector productivity measurement has been extensively studied and a system of productivity reporting has been established at the federal level, much research and additional work remain. Ambitious output definitions and measures for efficiency-type productivity measurement must be eliminated or refined, and innovative approaches to output measurement must be developed so that the system of productivity reporting can extend to areas such as research and development and defense activities. Future research efforts on input measures should be directed to developing measures that take into account changes in composition of labor input and include other factor inputs such as capital. These activities are applicable to productivity measurement for federal and state and local government activities although the approaches will have to vary depending on the nature of the activity.

At the same time, research directed toward the development of effectiveness-type measures should be continued. However, resolution of the conceptual and measurement problems for these types of measures may be less promising.

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Part IV. International Comparisons

Comparable measures of productivity and labor costs for industrial countries are described here. The first report represents the latest in a regular, annual series, and shows how the measures are applied and analyzed. The broad international setting within which significant differences in productivity trends occur is discussed, and some of the reasons for the differences are suggested.

Background

From its inception, the Bureau has collected and published statistical information on labor conditions and developments abroad. Foreign labor research and statistical analyses have been undertaken because (1) information on labor conditions published by a majority of foreign countries is not readily available to U.S. labor representatives, employers, Government officials, and others, and is often not available in English; (2) often, only an expert can judge the quality of foreign statistical sources; (3) comparisons between U.S. and foreign labor conditions shed light on U.S. economic performance relative to other industrial nations; and (4) comparisons provide information on the competitive position of the United States in foreign trade, which has an important influence on the U.S. economy and employment.

Description of measures

The BLS foreign labor statistical reports cover a variety of international comparative measures, mainly for the Western industrial countries. The principal measures cover the labor force, employment, and unemployment; productivity and labor costs; hourly compensation of manufacturing production workers; and trends in consumer prices.

Productivity and labor costs. Comparative trends in manufacturing productivity (output per hour), hourly compensation, unit labor costs (labor compensation per unit of output), and related measures are compiled on an annual-average basis for the United States, Canada, Japan, Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden, and the United Kingdom. Trends are expressd in index form (1977 = 100) and as percentage changes at annual rates. For most countries, the series begin with 1950. Indexes of unit labor costs for foreign countries are calculated in national currency and in U.S. dollars converted at prevailing commercial exchanged rates.

Comparative levels and trends in productivity and labor costs in the iron and steel industry in the United States, Japan, France, Germany, and the United Kingdom have been compiled annually beginning with 1964. The measures express levels of foreign output per hour, hourly compensation, and unit labor costs relative to the U.S. level (United States = 100). They also show trends in index form (1977 = 100) and at annual rates of change.

Comparative levels (United States = 100) and trends (1977 = 100) in gross domestic product (GDP), GDP per capita, and GDP per employed person are calculated on an average-annual basis for th United States, Canada, Japan, Belgium, France, Germany, Italy, the Netherlands, and the United Kingdom beginning with 1950. The GDP level comparisons, which are based on estimated purchasing-power-parity exchange rates, are benchmarked to data from the United Nations International Comparison Project. Purchasing-power-parity exchange rates represent the number of foreign currency units required to buy goods and services equivalent to what can be purchased with one unit of U.S. currency. A common practice has been to base such comparisons on official market exchange rates. However, market exchange rates seldom reflect the relative purchasing power of different currencies.

Hourly compensation. Measures of total compensation per hour worked for production workers in all manufacturing and in over 30 selected manufacturing industries are prepared annually for about 30 countries. The measures are developed from data on average earnings, as published by each country, plus information on other direct payments to the workers and employer expenditures for legally required insurance programs and contractual and private benefit plans. They are expressed in national currency and in U.S. dollars at prevailing commercial exchange rates. Hourly compensation, when converted to U.S. dollars at commercial exchange rates, indicates comparative levels of employer labor costs. It does not indicate relative living standards of workers or the purchasing power of their income. Prices of goods and services vary greatly among countries and commercial exchange rates are not reliable indicators of relative differences in prices.

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Analysis and presentation

Analyses of international labor statistics focus upon comparisons with U.S. data. Wherever possible, foreign data are adjusted to U.S. definitions and concepts to facilitate comparisons; for example, the adjustment of foreign unemployment rates to approximate U.S. concepts and the adjustment of production worker earnings to total hourly compensation.

Productivity and unit labor cost data are analyzed to explain the relative contributions of changes in output, employment, average hours, compensation, and exchange rates upon changes in the measures. Changes in employee compensation are analyzed to determine the relative contributions of direct pay and other elements of compensation.

The presentation of foreign labor statistics varies with the degree of analysis and major use of the data. Comprehensive bulletins have been published, covering manufacturing productivity and labor cost trends, steel productivity and costs, unemployment and labor force comparisons, and youth unemployment comparisons. For more current developments, articles are published periodically in the *Monthly Labor Review*. Also, an annual news release is issued on comparative trends in manufacturing productivity and labor costs. The *BLS Handbook of Labor Statistics* and the Bureau of the Census' *Statistical Abstract of the United States* publish many of the principal foreign data series, and some series are published in the annual *Economic Report of the President*. Many unpublished tabulations of current comparative data are available on request.

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International trends in productivity and labor costs

Output per employee hour in manufacturing generally improved and unit labor cost trends moderated in the U.S. and 10 other nations in 1981; relative productivity and labor cost indexes are introduced

PATRICIA CAPDEVIELLE, DONATO ALVAREZ, AND BRIAN COOPER

Manufacturing productivity increased in 1981 in the United States, Japan, and most European countries studied, with gains ranging from about 2 to 4 percent in the United States, Japan, France, Germany,[1] Italy, and the Netherlands, to almost 6 percent in the United Kingdom and Denmark, and more than 7 percent in Belgium. In Canada and Sweden, productivity remained essentially unchanged.

These productivity changes occurred in what was for most countries the second year of recession. In most European countries, productivity rose because employment and hours declined more than output. In the United States, Canada, and Japan, productivity gains were accompanied by modest output growth—temporary recoveries from 1980 declines in the United States and Canada.

Unit labor cost increases, which reflect changes in both productivity and hourly compensation costs, ranged from 2 to 5 percent in Japan, Germany, Belgium, Denmark, and the Netherlands, up to 15 percent in France and 18 percent in Italy. When measured in U.S. dollars, however, unit labor costs declined substantially in all the European countries—5 to 20 percent—because of the sharp appreciation of the dollar, while rising 7 to 8 percent in Canada and Japan as well as in the United States.

While the 1981 appreciation of the dollar partially offset the lower long-term U.S. cost trend, unit labor costs in the United States nevertheless declined 29 percent between 1970 and 1981, relative to the average costs of our trade competitors. Unit labor costs in Canada, Belgium, Denmark, the Netherlands, and Italy also declined relative to those of their trade competitors while those of Japan, France, Germany, the United Kingdom, and Sweden increased.

This article describes developments in manufacturing productivity (as measured by output per hour), hourly compensation, and unit labor costs in 1981, and compares the 1980–81 trends with those of the 1974–75 recession, for the United States, Canada, Japan, France, Germany, Italy, the United Kingdom, and four smaller European countries—Belgium, Denmark, the Netherlands, and Sweden.[2] Percent changes in productivity, labor costs, and related measures for selected periods and for each year from 1973 are shown in tables 1 through 3;[3] percent changes are also presented for the eight European countries and for the 10 foreign countries combined.[4] (Annual indexes for the years 1950 to 1981 are available from the authors.) The data for 1981 are based on preliminary underlying statistics, while those for other recent years reflect revised underlying statistics for several countries.

Although the productivity measure relates output to the hours of persons employed in manufacturing, it does not measure the specific contributions of labor as a single factor of production. Rather, it reflects the joint effects of many influences, including new technology,

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capital investment, the level of output, capacity utilization, energy use, and managerial effectiveness, as well as the skills and efforts of the work force.

This article also introduces new measures of relative trends in productivity and labor costs. Table 5 presents indexes of relative output per hour, hourly compensation, and unit labor costs in national currency and in U.S. dollars for the 11 countries. Each relative index represents the ratio of a country's own index to a weighted geometric average of the corresponding indexes for the other 10 countries; the weights used to combine the other country indexes reflect the relative importance of each country as a manufacturing trade competitor (table 4).

Productivity trends

In 1981, manufacturing productivity increased by more than 7 percent in Belgium, almost 6 percent in the United Kingdom and Denmark, and about 2 to 4 percent in the United States, Japan, France, Germany, Italy, and the Netherlands. In Canada and Sweden, it rose less than 0.5 percent. (See table 1.)

For the United States, the 1981 productivity gain was the largest annual increase since 1976. And for Belgium and the United Kingdom, the 1981 gains were the largest in many years. For Japan and Italy, the 1981 increases represent substantial slowdowns from large 1980 gains, but for most other countries, they were improvements over small gains or productivity declines in the previous year.

Output. With the exception of a small gain in Denmark, manufacturing output fell in each of the European countries in 1981—by more than 6 percent in the United Kingdom and about 1 to 4 percent in the other countries. In the non-Scandinavian countries, productivity increased because employment and hours declined even more than output. Most of Denmark's productivity gain also resulted from decreases in employment and hours. In Sweden, hours and output fell equally.

The 1981 drop in British output followed an even larger 1980 decline of 9 percent. For France and Belgium, 1981 marked the second consecutive year of declining output, but the 1980 declines were under 1 percent. Germany, Denmark, Sweden, and the Netherlands had zero or only slight 1980 output increases—under 1 percent—while Italy had a more substantial gain. In most countries, output turned down during the first half of 1980, and showed little if any recovery by late 1981 or early 1982. Only in Italy did output recover in late 1980 and turn down again in 1981.

In the United States and Canada, 1980 manufacturing output levels declined about 3 to 4 percent from previous year levels, but 1981 annual output levels were up 2 percent. In both countries, manufacturing production dropped in the second quarter of 1980, recovered in the fourth quarter, then turned down again during the second half of 1981. In Japan, manufacturing output increased more than 9 percent in 1980, and rose another 3 percent in 1981, but then turned down during the first half of 1982.

Table 1. Annual percent changes in manufacturing productivity and output, 11 countries, 1960–81

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom	Belgium	Denmark	Netherlands	Sweden	Eight European countries	Ten foreign countries
Output per hour:													
1960–81	2.7	3.6	9.2	5.5	5.2	5.8	3.6	7.2	6.1	7.1	5.0	5.3	5.9
1960–73	3.0	4.5	10.7	6.0	5.5	6.9	4.3	7.0	6.4	7.6	6.7	5.8	6.4
1973–81	1.7	1.4	6.8	4.6	4.5	3.7	2.2	6.2	4.1	5.1	2.2	4.1	4.7
1974	−2.4	2.2	2.4	3.5	5.4	4.9	.8	5.8	3.3	8.3	3.6	4.1	3.8
1975	2.9	−2.6	3.9	3.1	5.3	−4.4	−2.0	4.4	10.4	−1.8	−.4	1.6	2.0
1976	4.4	5.3	9.4	8.2	7.1	8.6	4.0	10.4	3.8	12.8	1.0	7.2	7.5
1977	2.5	4.0	7.2	5.1	4.9	1.1	1.6	6.5	2.1	4.1	−1.5	3.3	4.3
1978	.9	1.6	7.9	5.7	3.3	3.0	3.3	5.0	2.4	6.6	4.3	4.0	4.9
1979	.7	1.7	8.9	4.9	4.9	7.3	3.3	6.5	5.8	4.9	8.4	5.3	6.1
1980	.2	−3.3	6.8	1.6	1.4	5.8	.6	3.1	1.4	1.3	1.2	2.8	3.6
1981	2.8	.3	3.2	1.6	2.7	3.4	5.9	7.3	5.6	3.1	.1	3.8	3.3
Output:													
1960–81	3.6	4.8	10.0	5.2	3.8	5.4	1.6	5.0	4.0	4.7	3.2	4.0	5.3
1960–73	4.7	6.3	13.0	6.6	5.2	6.8	3.0	6.5	5.2	6.4	5.1	5.4	6.8
1973–81	2.3	2.0	6.5	2.3	1.9	3.3	−1.7	1.1	1.8	1.7	−.3	1.5	2.9
1974	−4.2	3.6	−2.0	3.2	−.3	6.4	−1.2	4.6	1.5	4.4	4.8	1.8	−.9
1975	−7.1	−5.9	−4.0	−2.1	−4.8	−9.7	−7.0	−7.4	−2.1	−6.7	−1.5	−5.2	−5.0
1976	9.6	5.9	13.3	7.0	8.0	12.6	2.0	8.6	4.8	8.0	−.4	7.0	8.5
1977	6.9	2.0	7.3	3.7	2.4	2.1	1.9	.7	.6	.9	−5.6	2.1	3.5
1978	5.3	5.0	7.3	3.2	1.3	1.8	.6	.9	.7	2.8	−1.3	1.6	3.4
1979	2.7	4.7	9.9	2.6	4.8	6.7	.2	3.7	6.5	2.7	6.9	3.8	5.6
1980	−4.3	−3.1	9.4	−.1	.5	6.3	−9.1	−1.4	.0	.9	.0	−.4	2.4
1981	2.3	1.6	3.2	−2.7	−1.4	−1.0	−6.3	−2.5	.5	−.9	−3.6	−2.4	−.4

NOTE: Rates of change computed from the least squares trend of the logarithms of the index numbers.

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Employment and hours. Manufacturing employment and aggregate hours both increased only in Canada in 1981; in Japan, employment rose slightly but total hours were essentially unchanged. In 1980, hours had increased slightly in Canada and by more than 2 percent in Japan. In the United States, employment and hours declined only slightly in 1981, after falling more than 3 percent in 1980. (See table 2.)

In Europe, employment declined 10 percent in the United Kingdom and 2 to 6 percent in the other countries in 1981. Those declines followed 1980 drops of 6 percent in the United Kingdom and 1 to 2 percent in most of the other countries. Employment had increased slightly in Germany in 1980 and was essentially unchanged in Italy and Sweden. Aggregate hours fell even more than employment in 1981—except in Denmark—as average hours were also reduced.

Comparisons with 1974–75. Comparisons of developments during the years 1980 and 1981 with the recession of 1974–75 cannot be precise, particularly when dealing with annual average data, because of differences among countries in the extent and timing of the 1974–75 recession and the 1980–81 downturns. Nevertheless, certain broad comparisons can be made.

Over the 1974–75 period, manufacturing output fell in one or both years in all 11 countries studied. During 1980–81, neither Japan nor Denmark experienced annual average declines in output, although Denmark had virtually no output growth over the period and Japanese output slowed sharply in 1981; most of the other countries had smaller output declines than in 1974–75. However, there were exceptions. The recent output declines in the United Kingdom were substantially greater than during 1974–75, and those in France and Sweden also appear to have been larger. Only in the United States did output regain its pre-1974 average rate of growth during the 1976–79 recovery period.

As in the case of output, manufacturing employment and hours declined less sharply during 1980–81 than during 1974–75 in most of the countries studied. For example, German employment declined about 2 percent in 1980–81, compared with 9 percent in 1974–75, and total hours declined 5 percent versus 15 percent. Again, major exceptions were France, where employment and hours declined somewhat more in 1980–81, and the United Kingdom, where the recent declines—16 percent for employment and 21 percent for total hours—were substantially greater than those in 1974–75. In Sweden, the employment effects of the 1974–75 recession were delayed; therefore, direct comparison between the two periods is not appropriate.

Although employment losses over the 2-year period of 1980–81 were less severe in most countries than in 1974–75, employment in most of Europe also declined during the intervening 1976–79 period. The rate of decline ranged from about 1 percent per year in France and Germany to almost 4 percent annually in Belgium. Only in Denmark and Italy was employment essentially stable during the recovery period. By 1981, employment in manufacturing was down 6, 11, and 14 percent from 1973 levels in Sweden, France, and Germany; 17 percent in Denmark and the Netherlands; and almost 25 percent in Belgium and the United Kingdom. In contrast, employment in the United States and Canada was higher in 1981 than in 1973.

All European countries have taken actions, through collective bargaining or government programs, to shorten average hours worked to preserve manufacturing jobs. Most countries have partial unemployment benefit programs to provide wage replacement to employees on short work schedules for economic reasons. In addition, minimum annual holiday (vacation) entitlements have been increased in Denmark, Germany, the Netherlands, Sweden, and the United Kingdom (and are scheduled to increase in France) as a job creation measure as well as a fringe benefit improvement. (In Italy, on the other hand, several national holidays were abolished in 1977 as a labor cost cutting measure, although many employees receive extra annual holidays in lieu of the national holidays.) In Belgium, the standard workweek was shortened through collective bargaining from 40 hours in 1977 to 38 hours for most employees in 1981; the shorter hours are provided as either a shorter workweek or a longer annual holiday.

Given the relative output and employee-hours changes, manufacturing productivity increased in most countries during both the 1974–75 recession and in 1980–81. The following tabulation shows average annual productivity changes over the two periods:

	1974–75	*1980–81*
United States	0.2	1.5
Canada	–.2	–1.5
Japan	3.2	5.0
France	3.3	1.6
Germany	5.4	2.1
Italy	.2	4.6
United Kingdom	–.6	3.2
Belgium	5.1	5.2
Denmark	6.8	3.5
Netherlands	3.2	2.2
Sweden	1.6	.7

In the United States, Japan, Italy, and the United Kingdom, the productivity trend was higher during 1980–81, while productivity gains were higher during 1974–75 in France, Germany, Denmark, the Netherlands, and Sweden. In Belgium, productivity rose equally in both periods. In Canada, productivity declined in both periods.

Hourly compensation

Hourly compensation increases in 1981 varied considerably among the 11 countries studied. The

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Table 2. Annual percent changes in manufacturing employment and hours, 11 countries, 1960–81

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom	Belgium	Denmark	Netherlands	Sweden	Eight European countries	Ten foreign countries
Aggregate hours:													
1960–81	0.9	1.1	0.7	−0.2	−1.3	−0.4	−1.9	−2.1	−2.0	−2.3	−1.7	−1.2	−.6
1960–73	1.6	1.7	2.1	.6	−.2	−.1	−1.2	−.5	−1.1	−1.1	−1.5	−.4	.4
1973–81	.6	.5	−.3	−2.2	−2.5	−.4	−3.8	−4.8	−2.2	−3.2	−2.5	−2.4	−1.7
1974	−1.9	1.4	−4.3	−.3	−5.4	1.4	−2.0	−1.2	−1.7	−3.6	1.2	−2.2	−2.7
1975	−9.7	−3.4	−7.6	−5.0	−9.6	−5.5	−5.1	−11.3	−11.3	−5.0	−1.1	−6.7	−6.8
1976	4.9	.5	3.6	−1.1	.8	3.8	−1.9	−1.7	1.0	−4.3	−1.5	−.2	1.0
1977	4.2	−2.0	.1	−1.3	−2.4	1.0	.2	−5.4	−1.4	−3.0	−4.1	−1.2	−.8
1978	4.4	3.4	−.5	−2.3	−1.9	−1.2	−2.6	−3.9	−1.7	−3.6	−5.4	−2.3	−1.5
1979	2.0	2.9	1.0	−2.2	−.1	−.6	−3.0	−2.6	.7	−2.1	−1.3	−1.5	−.5
1980	−4.5	.2	2.5	−1.7	−.9	.5	−9.6	−4.3	−1.4	−.4	−1.2	−3.1	−1.1
1981	−.5	1.3	−.1	−4.3	−4.0	−4.3	−11.5	−9.2	−4.8	−3.8	−3.7	−6.0	−3.7
Employment:													
1960–81	.9	1.4	1.5	.5	−.4	1.1	−1.1	−.7	−.7	−1.0	−.3	−.2	.3
1960–73	1.5	1.9	3.0	1.2	.5	1.4	−.5	.6	.2	.0	−.2	.5	1.1
1973–81	.7	.8	−.4	−1.4	−1.6	.0	−2.9	−3.6	−1.8	−2.4	−1.0	−1.7	−1.2
1974	−.4	2.0	.2	1.3	−2.6	2.5	1.9	1.1	−3.6	−.4	2.4	.3	.4
1975	−8.6	−2.2	−5.1	−2.7	−6.7	−.4	−3.8	−6.1	−8.4	−3.2	.9	−3.9	−4.2
1976	3.7	.4	.4	−1.0	−2.4	.2	−2.2	−4.1	.6	−4.0	−.2	−1.7	−1.0
1977	3.6	−2.0	−.2	−.5	−.8	.1	−.4	−3.9	−.5	−2.7	−3.5	−.7	−.6
1978	4.2	3.2	−1.1	−1.6	−.6	−1.0	−2.4	−4.1	−.5	−2.5	−2.8	−1.5	−1.2
1979	2.6	3.7	−.1	−1.8	.3	.5	−2.5	−2.7	.8	−1.0	.3	−.9	−.5
1980	−3.4	.3	2.5	−1.3	.6	.2	−6.0	−1.9	−2.0	−1.2	−.1	−1.6	−.3
1981	−.5	1.8	.5	−3.6	−2.4	−1.9	−10.1	−5.5	−4.8	−3.3	−3.2	−4.5	−2.8
Average hours:													
1960–81	−.1	−.3	−.8	−.7	−.9	−1.4	−.9	−1.4	−1.3	−1.2	−1.4	−1.0	−.8
1960–73	.1	−.2	−.9	−.5	−.8	−1.5	−.7	−1.0	−1.4	−1.1	−1.3	−.9	−.8
1973–81	−.2	−.3	.1	−.8	−.9	−.3	−1.0	−1.2	−.5	−.8	−1.5	−.9	−.5
1974	−1.5	−.6	−4.5	−1.5	−2.9	−1.1	−3.8	−2.2	2.0	−3.2	−1.1	−2.5	−3.1
1975	−1.2	−1.1	−2.6	−2.3	−3.1	−5.1	−1.3	−5.6	−3.2	−1.8	−2.0	−2.9	−2.8
1976	1.2	.1	3.2	−.1	3.2	3.5	.3	2.5	.4	−.3	−1.3	1.5	2.0
1977	.6	.0	.3	−.9	−1.6	.9	.6	−1.6	−.9	−.3	−.7	−.4	−.2
1978	.2	.3	.6	−.7	−1.4	−.2	−.2	.3	−1.2	−1.1	−2.6	−.8	−.3
1979	−.6	−.7	1.1	−.4	−.4	−1.0	−.5	.1	−.1	−1.1	−1.6	−.6	.0
1980	−1.0	−.1	−.1	−.3	−1.5	.3	−3.9	−2.5	.7	.8	−1.1	−1.5	−.8
1981	.0	−.5	−.6	−.7	−1.6	−2.4	−1.6	−3.8	.0	−.6	−.6	−1.6	−.9

NOTE: Rates of change computed from the least squares trend of the logarithms of the index numbers.

smallest gain was 5 percent in the Netherlands and the largest, 22 percent in Italy. In the United Kingdom and France, the increases were also large—over 16 percent. In Japan and Germany, the gains were relatively small—under 8 percent—while in the United States, Canada, Belgium, Denmark, and Sweden, they were 9 to 12 percent. (See table 3.)

Four countries—the United States, Germany, Denmark, and the United Kingdom—showed some degree of moderation in hourly compensation gains for 1981. In the United Kingdom, there was a substantial slowdown from the 24 percent recorded in 1980. (In the Netherlands, a significant slowdown occurred in 1980.) In Canada, Japan, Italy, and Sweden, however, the 1981 increases were higher than those of the previous year, and in France, Belgium, and the Netherlands, the increases in both years were virtually the same.

Compared with the hourly compensation trend during the 1974–75 recession, annual rates of increase during the 1980–81 period were considerably lower in every country except the United States and France. In the United States, however, the 1974–75 increases were relatively small. The moderation in wage gains and other labor costs occurred even though consumer price trends were generally about as high in 1980–81 as in 1974–75—with Japan and Belgium as principal exceptions. However, growing concern with moderating labor costs and containing inflation, as well as preserving manufacturing jobs, had a significant impact on recent compensation trends.

Concerted action was taken in several countries to moderate wage settlements during 1980–81. Temporary pay freezes were imposed in Belgium and the Netherlands and a temporary price freeze was undertaken in Sweden. The Dutch government subsequently imposed statutory pay controls. In several countries with wage indexation systems, the price indexes used were adjusted to exclude fuel and energy prices, or the cost-of-living allowances (COLA's) normally payable were reduced or rescinded.

In Japan and Germany, annual wage agreements in 1980 and 1981 continued the moderate pattern of recent years. In Japan, the average manufacturing settlement was 6.7 percent in 1980 and 7.6 percent in 1981, and in Germany, the average settlements were 6.7 percent in 1980 and 4.6 percent in 1981. In the United States and

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the United Kingdom, wage-and-salary concessions were made in some impacted companies or industries.

In the Netherlands, a pay freeze was imposed from January through April 1980, followed by statutory controls which were later extended through 1981. No basic wage increases were allowed. Furthermore, the June 1980 cost-of-living adjustment was restricted to a flat-rate amount, and the January 1981 adjustment was reduced by 2 percent. In 1981, holiday bonuses were lowered slightly, and extra annual holidays delayed.

The Belgian Government imposed a pay freeze in January 1981. The national wage agreement signed in February, under threat of statutory pay controls, provided either a 1-percent wage rate increase or an extra hour off the standard workweek by 1983. Wages are indexed for consumer price increases in Belgium, however, and the indexation system was not changed. The emphases of recent wage settlements in Belgium have not been basic wage increases but reductions of standard hours. Standard weekly hours were reduced from 40 hours per week in 1977 to 38 hours for most workers by 1980, and the 1981 national agreement allowed additional reductions. Because wage rates are adjusted to compensate for the shorter workweek, the hours reductions are measured as hourly compensation gains.

Wage rates are also indexed for consumer price increases in Italy, and cost-of-living allowances are paid under collective agreements in Denmark, Sweden, and the United Kingdom. In Italy as in Belgium, the indexation system continued unchanged during 1980–81. In Denmark and Sweden, COLA payments were restricted. In Denmark, the index used to compute the COLA's was changed in December 1979 to exclude fuel and energy prices, and was also rebased. As a result, one of the COLA's was eliminated in 1980. In Sweden, the 1981 pay agreements specified exclusion of energy prices from the consumer price index used in COLA computation. The government imposed a price freeze in September 1981 and cut value-added taxes in November, and thereby kept the price rise below the COLA threshold (trigger) specified in the pay agreement.

In Denmark, early 1981 wage settlements at the industry level provided moderate wage increases and restricted additional company-level wage negotiations. In

Table 3. Annual percent changes in hourly compensation and unit labor costs in manufacturing, 11 countries, 1960–81

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom	Belgium	Denmark	Netherlands	Sweden	Eight European countries	Ten foreign countries
Hourly compensation:													
1960–81	6.9	8.7	14.8	11.9	10.1	16.2	13.1	12.6	13.2	12.9	12.0	12.0	11.9
1960–73	5.0	6.4	14.6	9.2	9.3	12.3	8.6	10.7	11.8	12.8	10.4	9.8	10.1
1973–81	9.6	11.1	9.7	15.1	9.4	19.8	19.1	12.1	12.5	9.7	13.0	13.7	12.4
1974	10.6	15.8	31.2	19.6	15.0	24.6	25.0	22.5	21.0	19.2	17.6	18.3	21.4
1975	11.9	14.2	17.0	19.0	12.4	28.9	29.9	21.4	19.3	14.3	21.2	18.4	18.0
1976	8.0	14.2	6.7	14.1	7.8	19.8	17.2	13.2	11.7	12.5	18.5	13.0	11.2
1977	8.3	11.0	9.7	13.7	10.5	18.8	12.6	12.0	10.6	8.6	9.2	12.0	11.3
1978	8.3	6.7	5.9	12.7	8.5	14.5	16.5	8.0	10.2	8.7	11.3	11.6	9.8
1979	9.7	10.1	6.5	13.8	7.3	17.6	18.9	7.7	11.8	7.8	7.8	12.4	10.7
1980	11.8	9.1	6.5	16.6	8.6	18.5	23.6	9.6	10.9	5.0	10.9	14.9	12.0
1981	10.2	11.1	7.4	16.5	7.5	22.3	16.2	9.6	9.3	5.3	12.4	13.8	11.5
Unit labor costs:													
1960–81	4.1	4.8	5.1	6.1	4.6	9.8	9.2	5.1	6.8	5.5	6.7	6.3	5.8
1960–73	1.9	1.8	3.5	3.1	3.7	5.1	4.1	3.5	5.1	4.8	3.5	3.8	3.5
1973–81	7.7	9.5	2.7	10.0	4.7	15.5	16.6	5.6	8.0	4.4	10.6	9.2	7.4
1974	13.3	13.3	28.1	15.6	9.1	18.7	24.1	15.7	17.1	10.0	13.5	13.7	17.0
1975	8.8	17.2	12.6	15.4	6.8	34.9	32.5	16.3	8.0	16.4	21.7	16.6	15.6
1976	3.4	8.4	−2.5	5.5	.6	10.4	12.7	2.5	7.6	−.3	17.3	5.5	3.5
1977	5.7	6.7	2.4	8.2	5.3	17.5	10.8	5.2	8.4	4.3	11.0	8.4	6.7
1978	7.4	5.0	−1.8	6.6	5.0	11.2	12.8	2.9	7.6	1.9	6.7	7.2	4.7
1979	9.0	8.3	−2.2	8.5	2.4	9.6	15.0	1.1	5.7	2.8	−.5	6.7	4.3
1980	11.6	12.8	−.2	14.8	7.0	12.1	22.9	6.4	9.4	3.7	9.6	11.8	8.1
1981	7.2	10.7	4.0	14.6	4.7	18.3	9.7	2.1	3.5	2.1	12.3	9.7	7.9
Unit labor costs in U.S. dollars:													
1960–81	4.1	4.4	7.9	6.5	9.1	7.6	7.1	7.8	7.9	8.7	7.7	7.6	7.2
1960–73	1.9	1.9	4.9	2.8	6.1	5.4	2.6	4.6	5.0	6.1	4.2	4.2	3.9
1973–81	7.7	6.5	7.2	9.4	9.1	8.1	15.0	8.6	7.7	8.0	9.6	9.9	8.8
1974	13.3	15.8	19.0	6.7	11.9	6.2	18.5	15.5	16.0	13.9	11.5	11.4	13.5
1975	8.8	12.7	10.7	29.6	12.3	34.5	25.8	23.2	14.6	23.8	30.2	22.6	19.3
1976	3.4	11.9	−2.4	−5.4	−1.8	−13.3	−8.5	−2.5	2.1	−4.8	11.5	−5.0	−3.8
1977	5.7	−1.0	13.3	5.1	14.2	10.5	7.1	13.3	9.1	12.3	8.2	10.0	9.9
1978	7.4	−2.1	26.2	16.5	21.6	15.6	24.0	17.3	17.3	15.8	5.6	18.8	19.3
1979	9.0	5.4	−6.5	14.7	12.0	12.0	27.3	8.4	10.6	10.7	4.8	14.5	8.2
1980	11.6	13.0	−3.5	15.7	8.1	8.9	34.6	6.8	2.2	4.8	11.1	13.6	8.6
1981	7.2	8.0	6.7	−10.5	−15.7	−10.6	−4.5	−19.5	−18.0	−18.5	−5.7	−12.0	−7.4

NOTE: Rates of change computed from the least squares trend of the logarithms of the index numbers.

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France, there were no government restrictions on wage increases during 1980–81, and wage rate increases followed the consumer price index although there is no formal indexation system. Minimum-wage increases above the price index rate raised average wages further in some lower wage industries. In Italy, the major wage agreements were concluded in 1979 and expired in late 1981. Their wage rate provisions and the indexation system were not limited, although there were discussions of labor cost reductions and indexation changes for 1982. In Italy and several other European countries, actions were taken to cut employers' social security tax rates, although in other cases tax rates were raised to finance system deficits.

Unit labor costs

Unit labor costs, which reflect the interplay between hourly compensation and output per hour, increased about 7 percent in the United States and 10 to 12 percent in Canada, Sweden, and the United Kingdom in 1981, compared with more than 14 percent in France and 18 percent in Italy, but only 2 to 5 percent in Denmark, Japan, Germany, Belgium, and the Netherlands. (See table 3.)

In every country except Japan, France, Italy, and Sweden, unit labor costs increased less in 1981 than in the previous year. In the United Kingdom, the slowdown from the 23 percent recorded in 1980 was substantial, and reflected both a smaller compensation increase and a larger productivity gain. In most other countries also, the moderation in unit labor costs reflects a slowdown in hourly compensation and improvements in productivity. In France, the 1981 increase in unit labor costs, as well as in productivity and hourly compensation, was essentially the same as the previous year's. In Japan and Italy, the acceleration in unit labor costs primarily reflects their productivity slowdowns.

The 1980–81 increases in unit labor costs were generally much smaller than those of 1974–75 because hourly compensation gains were relatively moderate, in contrast to the substantial wage gains during the 1974–75 recession. The average annual unit labor cost increases for the two periods are shown in the following tabulation:

	1974–75	*1980–81*
United States	11.0	9.4
Canada	15.2	11.8
Japan	20.3	1.9
France	15.5	14.7
Germany	7.9	5.9
Italy	26.8	15.2
United Kingdom	28.3	16.3
Belgium	16.0	4.2
Denmark	12.5	6.4
Netherlands	13.2	2.9
Sweden	17.6	10.9

For some countries—Japan, Belgium, Denmark, and the Netherlands—the differences are substantial. Even for the countries with the largest unit labor cost increases in 1980–81—Italy and the United Kingdom—the recent increases are down considerably from 1974–75 peaks. The differences are less marked for the United States and Germany, which had the smallest 1974–75 unit labor cost increases.

In U.S. dollars. In comparing trends in unit labor costs among countries, an important analytical element is the shift in relative currency values through international exchange rate adjustments. In recent years, the number and extent of such adjustments have been so great as to constitute a major variable in competitive assessment.

The relationship between exchange rate shifts and unit labor cost trends is partial and indirect but nonetheless important. The two are linked by the price mechanism, a main determinant of trade directions and competitive relationships. Because labor cost is the principal cost factor in the production of manufactured goods, it exerts a strong influence on the price at which goods can be offered in international markets. Relative changes in exchange rates alter the effect of relative changes in costs in national currency. Consequently, in assessing relative changes in unit labor costs in competitive terms, changes in exchange rates need to be taken into account.

Changes in currency exchange rates in 1981 had a significant effect on relative changes in unit labor costs measured in U.S. dollars. The dollar appreciated substantially—from about 15 percent to more than 30 percent—relative to the European currencies. (By September 1982, the dollar had further appreciated—compared with the annual average for 1981—10 percent versus the German mark and Dutch guilder, and 8 to 30 percent versus the other European currencies.) The dollar also appreciated somewhat relative to the Canadian dollar, but declined slightly versus the Japanese yen. (By September 1982, however, the dollar had appreciated 19 percent versus the yen, as well as another 3 percent versus the Canadian dollar.)

Therefore, when measured in U.S. dollars, unit labor costs in the European countries fell about 5 percent in Sweden and the United Kingdom; 11 percent in France and Italy; 16 percent in Germany; and 18 to 20 percent in Belgium, the Netherlands, and Denmark. In U.S. dollars, unit labor costs increased 8 percent in Canada and 7 percent in Japan—about the same rate as for U.S. costs. (See table 3.)

The largest contrast was between Japan and Germany. On a national currency basis, they had increases of 4 and 5 percent, respectively. On a U.S. dollar basis, Japanese unit labor costs rose 7 percent while German unit labor costs fell 16 percent.

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While the 5-percent decline in the United Kingdom was not as large as in the other European countries, it was the sharpest trend reversal among all the countries, for British unit labor costs had increased 35 percent in 1980. Unit labor costs in Japan had posted a small decline in 1980; among the other countries, they had risen 2 to 16 percent.

The trend in unit labor costs in U.S. dollars for the 1980–81 period differs significantly from that for the years 1974–75 in most countries covered. First, unit labor costs in national currency increased much less during 1980–1981 in most countries. Secondly, the U.S. dollar appreciated versus all European currencies and the Canadian dollar in 1981, while in 1974–75, the dollar appreciated versus the Japanese yen, Italian lira, and British pound but depreciated versus all the other currencies. Therefore, unit labor costs in U.S. dollars increased substantially more in most other countries than in the United States during the 1974–75 recession, while in the 1980–81 period, unit labor costs in U.S. dollars declined in all European countries covered.

Relative productivity and cost trends

Indexes of manufacturing productivity and labor costs are often used in analyses of changes in the relative competitive position of countries in the international trade of manufactures. Unit labor costs are an important element in determining the underlying price competitiveness of manufactured products, with relative productivity and hourly compensation trends determining unit labor cost performance. The International Monetary Fund (IMF) and Organization for Economic Cooperation and Development (OECD) publish indexes for key cost and price measures—including unit labor costs in U.S. dollars—which show the trend of each country's own indicators relative to those of other industrial (competitor) countries.[5] The BLS unit labor cost measures are used in the computation of the IMF and OECD indicators for most countries they cover. The following section introduces indexes of trade-weighted relative trends in manufacturing productivity, hourly compensation, and unit labor costs in national currency, as well as unit labor costs in U.S. dollars.

Because trade involves individual products, the use of aggregate manufacturing measures as indicators of trade competitiveness has certain limitations. In general, labor productivity growth rates in export sectors probably exceed those for manufacturing as a whole. On the other hand, hourly compensation tends to grow at similar rates in all manufacturing sectors within a country. Overall, therefore, trend measures for the total manufacturing sector would be expected to overstate, to some extent, the growth of unit labor costs for the export sector. However, this would probably be true for every country, and, in any case, the measures are intended to represent relative changes only. In addition, exchange rate changes have a significant effect on relative unit labor cost developments, and these affect unit labor costs in all manufacturing industries equally.

Index calculation methods. The indexes of relative trends in manufacturing productivity and labor costs represent ratios of each country's own indexes to weighted geometric averages of the corresponding indexes for the other 10 "competitor" countries.

The weights used to combine the other 10 countries' indexes into an average "competitors" index reflect the relative importance of each country as a manufacturing trade competitor. The weights are those developed by the IMF for computation of their own relative cost and price indicators—except that they have been adjusted from the 14-country coverage of the IMF series to the 11-country coverage of the BLS series.[6] The weights are based on disaggregated trade data for manufacturers in 1975. They take into account the relative importance of each country's trading partners in its direct bilateral trade with them and the relative importance of those partners in competition in "third country" markets, ad-

Table 4. Trade weights used to compute competitor indexes

[In percent]

Reference country	Competitor country										
	United States	Canada	Japan	Belgium	Denmark	France	Germany	Italy	Netherlands	Sweden	United Kingdom
United States	—	19.3	17.3	3.3	1.1	13.1	18.8	7.4	4.9	3.2	11.6
Canada	76.9	—	5.1	.9	.2	2.5	5.3	1.7	.9	2.0	4.5
Japan	36.2	2.9	—	3.8	1.4	11.3	18.2	7.4	4.4	3.7	10.8
Belgium	5.7	.5	6.2	—	.9	22.9	34.1	7.7	9.5	2.4	10.1
Denmark	12.7	.9	10.3	2.9	—	9.6	23.4	6.4	4.7	13.2	15.9
France	16.7	1.1	11.9	4.0	1.3	—	31.1	13.3	5.0	3.0	12.5
Germany	17.5	1.5	12.1	7.8	1.2	21.0	—	12.8	8.1	5.3	12.8
Italy	16.3	1.4	12.2	4.5	1.4	10.8	34.3	—	4.9	2.8	11.5
Netherlands	11.9	.7	9.1	8.7	1.5	16.5	33.9	4.2	—	2.7	10.7
Sweden	18.0	3.5	11.6	3.3	4.8	10.3	23.4	6.5	3.8	—	14.8
United Kingdom	25.0	2.0	11.6	5.4	2.1	13.7	22.5	7.8	5.3	4.7	—

NOTE: Because of rounding, sums of individual items may not equal 100.0.

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justed for the importance of foreign trade to the manufacturing sector as a whole in each country.[7] Table 4 shows the weights used for each of the 11 countries.

The relative indexes of output per hour, hourly compensation, and unit labor costs in national currency and in U.S. dollars are shown in table 5. The underlying "own country" and "competitor countries" indexes used to compute the relative indexes, and indexes of trade-weighted exchange rates, not shown in table 5, are available from the authors.

Relative productivity trends. The countries in which manufacturing productivity grew more rapidly than that of trade competitors since 1970 were Japan, Belgium, the Netherlands, and Denmark. Productivity had risen 11 to 12 percent more in Denmark and the Netherlands and 16 percent more in Japan and Belgium by 1976. By 1981, their relative trends had diverged: For Japan, productivity gains were 41 percent higher and for Belgium, 29 percent, while in Denmark and the Netherlands the gains were 12 and 13 percent higher.

Table 5. Relative indexes of output per hour, hourly compensation, and unit labor costs in manufacturing, 11 countries, 1970–81

[1970=100]

Year	United States	Canada	Japan	France	Germany	Italy	United Kingdom	Belgium	Denmark	Netherlands	Sweden
Output per hour:											
1970	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1971	100.7	101.2	101.0	100.4	98.9	98.1	98.7	101.4	101.2	101.7	100.0
1972	98.5	100.0	105.9	98.9	98.0	99.0	99.4	105.6	102.2	102.4	98.2
1973	96.5	100.3	109.5	96.9	96.2	103.8	98.4	109.2	105.2	105.5	98.3
1974	91.0	103.6	110.2	97.2	98.7	105.8	96.5	111.1	105.5	110.6	99.2
1975	92.6	98.4	112.3	98.4	102.9	98.1	92.1	113.4	114.6	105.4	96.5
1976	90.3	98.7	115.9	99.6	102.8	99.6	89.5	116.5	112.0	111.2	91.4
1977	88.8	99.8	120.4	101.0	104.2	96.6	87.5	119.2	110.7	111.0	86.6
1978	85.9	99.6	126.3	103.0	103.2	95.8	87.1	120.0	109.1	113.9	87.2
1979	82.3	99.4	132.9	103.0	103.1	98.3	86.0	121.7	109.8	113.9	90.4
1980	81.0	95.4	140.3	102.3	102.1	102.1	84.8	123.1	109.2	113.1	89.8
1981	81.1	93.0	140.5	100.6	101.6	102.3	87.4	128.5	111.9	112.9	87.0
Hourly compensation:											
1970	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1971	94.2	99.8	104.8	99.3	99.8	103.0	102.9	101.8	102.2	101.8	100.2
1972	88.7	99.9	110.5	99.2	98.7	106.1	105.1	105.6	101.3	104.6	100.7
1973	82.4	100.7	120.8	98.4	96.3	118.3	102.5	107.4	107.8	109.4	98.8
1974	75.4	103.0	136.3	98.7	91.8	124.4	108.7	110.5	109.3	109.7	97.4
1975	71.4	103.5	136.5	99.7	86.1	137.9	121.7	114.2	109.9	106.7	100.3
1976	68.6	108.4	130.6	102.3	82.0	149.7	128.8	115.6	109.2	108.1	106.8
1977	66.6	110.4	129.4	104.4	80.9	161.0	130.8	115.9	108.7	105.4	105.0
1978	65.8	108.2	124.3	107.0	79.2	168.3	139.5	113.2	108.4	104.1	106.1
1979	65.2	108.3	119.2	110.2	75.9	180.4	151.2	109.9	109.4	101.7	103.1
1980	65.3	105.5	112.5	114.8	72.6	192.1	168.4	107.2	107.8	95.2	101.6
1981	64.5	106.1	108.1	120.5	69.0	213.5	176.6	105.3	105.6	90.2	102.7
Unit labor costs in national currency:											
1970	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1971	93.6	98.6	103.7	98.9	101.0	105.0	104.3	100.4	101.0	100.1	100.2
1972	90.0	99.9	104.4	100.3	100.7	107.2	105.8	100.0	99.1	102.1	102.4
1973	85.4	100.4	110.3	101.6	100.1	113.9	104.2	98.4	102.5	103.7	100.5
1974	82.9	99.4	123.6	101.6	93.0	117.7	112.7	99.5	103.6	99.1	98.2
1975	77.1	105.2	121.5	101.3	83.6	140.6	132.1	100.7	95.9	101.3	103.9
1976	76.0	109.9	112.8	102.7	79.7	150.3	143.9	99.2	97.5	97.2	116.9
1977	75.0	110.6	107.5	103.4	77.7	166.5	149.6	97.2	98.2	94.9	121.2
1978	76.6	108.6	98.4	103.9	76.7	175.6	160.1	94.3	99.3	91.4	121.7
1979	79.3	108.9	89.7	107.0	73.7	183.5	175.7	90.3	99.7	89.3	114.1
1980	80.5	110.6	80.2	112.2	71.1	188.1	198.5	87.1	98.7	84.2	113.2
1981	79.6	114.0	76.9	119.8	68.0	208.6	202.2	82.0	94.3	79.9	118.1
Unit labor costs in U.S. dollars:											
1970	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1971	91.1	101.3	105.2	96.6	104.3	103.7	104.2	100.0	100.0	101.1	99.5
1972	81.5	102.6	116.1	100.3	106.4	104.6	101.2	102.0	97.7	104.4	102.6
1973	71.1	99.9	129.0	106.0	119.2	100.3	88.9	101.4	107.0	109.9	101.1
1974	70.9	102.1	136.6	99.9	118.6	93.8	93.8	104.9	109.8	111.2	99.4
1975	64.9	103.3	128.8	110.2	109.1	108.5	100.8	107.5	105.0	116.4	110.3
1976	68.1	113.5	127.4	107.6	111.0	95.9	93.5	109.1	109.2	113.9	126.4
1977	66.4	105.2	133.5	102.2	116.9	96.1	91.5	112.2	108.6	116.1	125.0
1978	61.7	93.5	148.2	101.0	122.7	94.2	98.4	111.1	109.0	113.7	112.4
1979	61.8	90.2	123.6	105.1	124.3	95.5	115.4	107.2	108.8	113.2	106.1
1980	62.4	91.5	105.7	110.3	120.2	94.1	143.2	102.8	99.2	106.7	105.9
1981	70.8	95.4	118.7	106.6	107.8	91.1	146.0	92.5	87.6	95.6	106.8

NOTE: Relative indexes are calculated from the ratio of the reference country index to a trade-weighted average index for the other 10 countries.

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In France, Germany, and Italy, productivity increased at about the same rate as that of trade competitors from 1970 to 1981. Their relative rates of change varied during the period, however. In the early 1970's, productivity in France and Germany rose somewhat less rapidly, and in Italy it rose more rapidly, but during the late 1970's, the relative rates were reversed.

Productivity rose less rapidly than in competitor countries for the United States, Canada, Sweden, and the United Kingdom. From 1970 to 1981, U.S. relative productivity had increased 19 percent less, while in Sweden and the United Kingdom, gains were 13 percent lower, and in Canada, 7 percent lower. The slower gains were quite consistent throughout the entire period.

Relative compensation trends. Hourly compensation rose less than in competitor countries in the United States, Germany, and the Netherlands. From 1970 to 1981, compensation increased about 35 percent less in the United States, 30 percent less in Germany, and 10 percent less in the Netherlands. For the United States and Germany, the slower relative trend was fairly consistent over the whole period. For the Netherlands, however, compensation rose more rapidly than competitors' during the early 1970's, then less rapidly after 1976, with the greatest relative declines occurring in 1980–81, following the imposition of wage controls.

Hourly compensation rose more rapidly than in competitor countries in Italy, the United Kingdom, Japan, and France. From 1970 to 1981, compensation had increased about 100 percent more in Italy and about 75 percent more in the United Kingdom. Almost without exception, both had consistently larger gains than their competitors throughout the 1970–81 period. Hourly compensation in Japan rose more rapidly during the early 1970's—by 1975, Japanese compensation had increased about 35 percent more than that of competitors—but grew less rapidly after 1975. By 1981, Japanese compensation gains were only 8 percent higher than competitors'. In France, hourly compensation rose at about the same rate as in competitor countries until the mid-1970's, then rose more rapidly to end in 1981 with about a 20-percent larger cumulative increase.

Canada, Belgium, and Denmark also ended the 1970–81 period with somewhat larger compensation increases. But in each country, the 1981 relative gains were down from previous peaks—in Canada, 6 percent down from 10 percent in 1977; in Belgium, 5 percent down from 16 percent in 1976–77; and in Denmark, 6 percent down from 9 percent in 1974–79. In Sweden, hourly compensation generally rose at about the same rate as competitor countries' over the 1970–81 period.

Relative unit labor cost trends. Unit labor costs in national currency increased less from 1970 to 1981 in six countries—the United States, Japan, Germany, Belgium, Denmark, and the Netherlands—than in their competitor countries. The relative trend was 6 percent lower in Denmark by 1981, and about 20 to 30 percent lower in the other countries.

The relative change for the United States was down because hourly compensation had fallen more than output per hour. In Japan, Belgium, and Denmark, relative productivity gains more than offset relative compensation increases; in Germany, the relative productivity trend was about level, but relative compensation was sharply down; and the Netherlands had both productivity and hourly compensation advantages.

The relative trend for the United States was steadily downward from 1970 to 1977, up moderately from 1977 to 1980, and down again slightly in 1981. Relative unit labor costs in Japan rose over 20 percent more than those of competitors by 1974–75, then declined steadily to 23 percent less than competitors' by 1981. Relative unit labor costs declined steadily in Germany from 1973, in Belgium and the Netherlands from 1975, and in Denmark from 1979. For the Netherlands, the most significant relative cost declines occurred during 1980 and 1981.

Unit labor costs in national currency increased by at least 100 percent more than competitors' in Italy and the United Kingdom and by about 15 to 20 percent more in Canada, France, and Sweden. The large relative increases in Italy and the United Kingdom are attributable to hourly compensation gains as the relative productivity trend was down in the United Kingdom and essentially level in Italy. In Canada and France, hourly compensation was up slightly, and the productivity trend was down in Canada and even in France. In Sweden, hourly compensation trends were equal to those of competitors, but productivity fell from 1970 relative levels.

In U.S. dollars. After adjustment for the relative change in the foreign exchange rate of the dollar, U.S. unit labor costs showed a decline of nearly 30 percent versus those of competitors from 1970 to 1981, compared with about 20 percent in national currency. In 1980, relative unit labor costs adjusted for the dollar exchange rate were down almost 40 percent. However, the U.S. dollar appreciated 10 percent against trade-weighted U.S. competitor currencies from 1980 to 1981. This primarily reflected the dollar's appreciation relative to the German mark, French franc, and British pound, because, on a trade-weighted basis, the 2.5-percent appreciation of the Japanese yen was balanced by a 2.5-percent depreciation of the Canadian dollar.

Unit labor costs adjusted for relative exchange rates for Canada, Italy, Belgium, the Netherlands, and Denmark were also down—5 to 12 percent—versus competitors. For Canada, a 16-percent decline in the

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exchange rate, primarily against the U.S. dollar, offset higher increases in unit labor costs in Canadian dollars. For Italy, the exchange rate posted a 55-percent decline versus U.S. and German currencies. On the other hand, trade-weighted exchange rates were up 13 and 20 percent for Belgium and the Netherlands; therefore, relative unit labor costs in dollars declined less than in national currency terms.

For Germany and Japan, unit labor costs in U.S. dollars increased 8 and 19 percent more than those of trade competitors (principally the United States for Japan, and France and the United States for Germany) even though unit labor costs in national currency were down about 25 to 30 percent, because their relative exchange rates rose 55 to 60 percent over the 1970–81 period.

In the United Kingdom, relative unit labor costs increased 100 percent in national currency terms, but 46 percent in U.S. dollars, because the British pound declined 28 percent overall against competitor currencies—primarily the dollar and the German mark. In France and Sweden, unit labor costs in U.S. dollars posted 1970–81 relative increases of 7 percent, as costs in national currency rose nearly 20 percent more than those of competitors, but trade-weighted exchange rates declined about 10 percent versus competitor currencies.

[1] The Federal Republic plus West Berlin.

[2] The data relate to all employed persons, including the self-employed, in the United States and Canada, and to all wage and salary employees in the other countries. Hours refer to hours paid in the United States, hours worked in the other countries.

Compensation includes all payments made by employers directly to their employees (before deductions), plus employer contributions to legally required insurance programs and to contractual and private welfare plans for the benefit of employees. Labor costs include, in addition to compensation, employer expenditures for recruitment and training; the cost of cafeterias, medical facilities, and other plant facilities and services; and taxes (other than social security taxes, which are part of compensation) levied on payrolls or employment rolls. Annual data are not available for total labor costs. As used in this article, labor costs approximate more closely the concept of compensation. However, compensation has been adjusted to include all significant changes in taxes that are regarded as labor costs. For the United States and Canada, compensation of self-employed workers is measured by assuming that their hourly compensation is equal to the average for wage and salary employees.

[3] Percent changes for 1960–81, 1960–73, and 1973–81 shown in the tables are computed using the least squares method—that is, from the least squares trend of the logarithms of index numbers—in order to remove much of the effect of cyclical changes on the average rates of change, and thereby estimate the underlying trends.

[4] To compute the series for the eight European countries and 10 foreign countries, the data have been combined by aggregating the output, compensation, and hours figures for each year, adjusting where necessary for compatibility of coverage and concept. Average exchange rates for 1974–81 were used to aggregate the output and compensation data. The use of 1974–81 exchange rates, however, does not imply that these rates reflect the comparative real value of currencies for manufacturing output. Moreover, the use of exchange rates for a different period would have little effect on the combined series.

[5] The IMF publishes annual and quarterly indexes of relative unit labor costs and relative normalized unit labor costs in manufacturing—as well as relative value-added deflators, relative wholesale prices, and relative export unit values in manufacturing—for 14 industrial countries, in their monthly statistical publication *International Financial Statistics*. The OECD publishes quarterly indexes in chart form of relative unit labor costs in manufacturing, relative export unit values (prices) for manufactures, and relative consumer prices for 15 industrial countries in their monthly statistical publication *Main Economic Indicators*.

Series descriptions, data sources, and compilation methods for the IMF measures are described in "Intercountry Cost and Price Comparisons," a paper by Michael C. Deppler, Research Department, International Monetary Fund (November 1979); the OECD measures are described in *The International Competitiveness of Selected OECD Countries*, OECD Economic Outlook Occasional Studies, July 1978.

[6] The IMF weights were derived from disaggregated 5-digit Standard International Trade Classification data (up to 1,400 individual commodity classes) for each of the 14 countries covered by their series. The IMF weights have been simply adjusted to the 11-country BLS comparative series by eliminating the weights for the three uncovered countries—Austria, Norway, and Switzerland—and proportionately increasing the weights for the remaining 11 countries so that they equal 100 percent. The result should be little different from a comprehensive reweighting based on trade data for the 11 countries alone, because the omitted countries account for no more than 8.1 percent of the total 14-country weight for any of the 11 countries, and for a total of only 4 percent in the case of the United States.

[7] The weighting system is described in detail in Deppler, "Intercountry Cost and Price Comparisons."

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THE INTERNATIONAL CONTEXT

Arnold Packer and
Arthur Neef

Productivity growth is a major determinant of a nation's ability to combat inflation, to maintain competitiveness in international trade, and to increase its standard of living. Gross domestic product (GDP) per employed person, which covers the economy's total output of goods and services, provides a broad measure of labor productivity. Over the period 1960 to 1979, real GDP per employed person increased at an annual average rate of 1.5 percent per year in the United States. This compares with annual average gains of around 2 percent in Canada and the United Kingdom, 4 percent in Belgium, France, Germany, the Netherlands, and Italy, and 7 percent in Japan. Roughly comparable figures for some rapidly developing economies are 5.4 percent for Korea, 5.8 percent for Taiwan, and 3.3 percent for Mexico (1960–1977).

Since 1973, the average rate of gain in real GDP per employed person in the United States has been only 0.3 percent per year; in the period from 1960 to 1973 it was 2.1 percent per year. Since 1973, other industrial countries have also experienced productivity slowdowns—some as sharp as the United States' slowdown. With the exception of Canada, however, all continued to have larger annual average gains in GDP per employed person.

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GDP per employed person does provide a measure of economy-wide productivity, but it also has some shortcomings. Let us briefly note the most relevant. GDP covers the area of public administration, though the United States and most other countries assume zero productivity growth for this sector because of measurement difficulties. GDP does not take into account changes in average hours worked. And it includes the effects of resource shifts among sectors with very different levels of productivity (all the countries mentioned above have undergone shifts in relative employment as workers moved between agriculture, industry, and services).

For some purposes of analyzing international competitiveness, manufacturing productivity, as measured by output per hour, is a better indicator. Manufacturing productivity exhibits a pattern similar to GDP per employed person, with the U.S. showing the smallest average rate of gain since 1960. Also, all the Western industrialized countries show a manufacturing productivity slowdown since 1973—although, for most countries, a less significant slowdown than for GDP. For nations such as France, West Germany, and the Benelux countries, output per hour in manufacturing slowed much less than GDP per employed person because of significant reductions in average working hours. The U.S. rate of growth since 1973 of 1.4 percent per year—compared with 3 percent per year from 1960 to 1973—exceeded the rate of labor productivity gain in the United Kingdom, but was less than in any of the other countries compared.

While the United States has had the slowest rate of productivity growth, it still exceeds any other country in overall efficiency. As of 1979, GDP per employed person in Canada was about 95 percent of the U.S. level; in France, Germany, and the Benelux countries, it was around 90 percent; in Japan, two-thirds of the U.S. level; and in Italy and the United Kingdom, 60 percent. Because of the faster rates of productivity growth abroad, there has been a narrowing—in some cases a very substantial narrowing—of the productivity gap. In 1960, the corresponding figures were, Canada, 90 percent of the U.S. level; France, Germany, the Benelux countries, and the United Kingdom, about 55 to 60 percent; Italy, 35 percent; and Japan, only 25 percent. Unfortunately, similar level comparisons for manufacturing are not available.

The much lower relative levels of productivity in Japan and Europe in 1960 partially explain their faster rates of productivity growth. Comparative rates of productivity growth between the United States and countries approaching the U.S. overall level of efficiency should, presumably, narrow.

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However, many other factors also affect relative rates of productivity gain.

Despite the fact that the U.S. had the lowest rate of productivity growth among Canada, Japan, and all Western European countries from 1960 to 1979, manufacturing unit labor costs rose less in the United States than in any of the other countries. And for good reason. These countries had larger gains in hourly compensation—in Japan and Europe, roughly double the U.S. average yearly increase of about 6½ percent. U.S. unit labor costs rose at an average rate of 3.7 percent per year, compared with about 4 percent per year in Canada, 4.5 percent per year in Japan, Belgium, and Germany, 5.5 percent in the Netherlands, 6 percent in France, and around 9 percent in Italy and the United Kingdom.

While relative changes in nominal unit labor costs potentially affect trade competitiveness, unit labor costs adjusted for changes in exchange rates are the more relevant measure. Over the years, particularly since the 1971 and 1973 devaluations of the U.S. dollar, there have been substantial shifts in currency valuations—which have a significant impact on rates of change in unit labor costs. In general, the currencies of Japan, Germany, and the smaller European countries have appreciated relative to the U.S. dollar, while the British and Italian currencies have depreciated. From 1960 to 1979 the French franc has also appreciated somewhat while the Canadian dollar, because of substantial declines in the past few years, has depreciated.

After adjustment for these shifts in exchange rates, Canada shows a lower rate of gain in unit labor costs since 1960 than the United States while Germany and the Netherlands show the highest average rates of gain—about 9 percent per year. In the period since 1973, Canada also had a smaller gain than the United States in unit labor costs as measured on a U.S. dollar basis. However, Japan, Germany, Belgium, and the Netherlands, which had smaller national currency-based rates of increase than the U.S. increase of 8 percent per year, show average gains of about 9 to 12 percent per year.

Labor productivity gains are the principal means of raising living standards. Increases in output per hour can be translated into greater output of goods and services or into increased leisure time. Changes in real hourly compensation are one measure of changes in living standards. For the economy as a whole, real hourly compensation of workers can only increase if output per hour increases or labor receives an increasing proportion of total factor incomes. Of course, individual workers or workers in particular industries can also receive real gains in hourly compensation at the expense of other workers.

Real hourly compensation of U.S. manufacturing workers, using the consumer price index as the price measure, rose at an average rate of 1.4 percent per year from 1960 to 1979. In the period up to 1973, real hourly compensation rose 1.7 percent per year; from 1973 to 1979, only 0.8 percent per year. While the gains in real hourly compensation were less than either the total economy or manufacturing productivity gains, the pattern was similar—a substantially reduced rate of increase in the period of the productivity slowdown.

Manufacturing workers in all of the other countries had much larger increases in real hourly compensation, ranging, over the 1960 to 1979 period, from double the U.S. average rate of gain in Canada to over four times the U.S. average rate of gain in Japan and the continental European countries. But because of substantial reductions in average working hours in Japan and Europe, increases in real hourly compensation overstate the increases in real income from work. Still, the increases were noticeably greater than in the United States.

World War II left much of the industrialized world in ruins. In most of the major countries, and in the former Axis powers in particular, the process of economic development was either arrested or set back many years. In contrast, the war greatly accelerated the development of the U.S. economy. Since the U.S. economy was already the most highly developed before the war started, in 1945 productivity and per capita income in the U.S. were far higher than in other countries.

In 1945, the United States was at the frontier of technology. But the secrets to higher productivity technology could be bought from the U.S. through patent licenses and other technical agreements.

A comparison of the relevant countries' imports and exports of technology will illustrate the point. In 1971 the ratio of Japanese payments for imports of technology (patent licenses, know-how, and associated expenses) to Japanese receipts for technology exports was about eight to one. In Germany, this ratio was nearly three to one, and in France it was close to two to one. In the more mature economies of Great Britain and the U.S., however, receipts outweighed payments. For Britain, the difference was small; but U.S. payments for technology stood at only $218 million while receipts weighed in at a whopping $2.5 billion.

In many fields, the U.S. is still operating on the technological frontier. As industrialized countries approach technological parity, the spectacular gains attained in Germany and Japan will continue to diminish.

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Part V. Technology Studies

One of the important efforts of BLS has been to examine the impact of technological change upon productivity, employment, and occupational change. This part describes the scope of this research, including the sources and data collection methods. A study of the employment effects of new electronic technology is included, together with a representative series of studies of technological change and its effect upon labor and other economic variables. Projections of possible future effects of specific technologies on employment and occupational structure are also included.

Background

Studies of technological changes and their labor implications have been undertaken by BLS over the years for a variety of purposes. During the 1930's, public interest focused on the unemployed, and reports were prepared on technological changes and displacement of workers in various industries. During World War II, emerging technologies were studied for purposes of improving manpower utilization.

Beginning in the mid-1950's, nationwide attention was focused on the implications of new developments classified under the general term "automation." BLS made a series of studies on a plant basis, in the insurance, petroleum refining, bakery, air lines, and electronics industries, to explore the manpower implications of various changes. Later, broader studies were undertaken, including a survey of the manpower impact of changeover to electronic computers in 20 large companies and intensive studies of technological change in the coal and paper industries.

These studies formed the basis, beginning in the early 1960's, for a more systematic investigation of future changes. Research now underway pinpoints technologies which will become increasingly important over the next decade in key industries and attempts to provide advance information about their manpower implications.

Description of Studies

The Bureau's research program on technological change involves a variety of reports and studies of different degrees of detail and approach. The current program thus provides: Summary reports surveying trends in major industries; detailed industry studies; and studies of major technological innovations, such as computers, that affect workers in different industries.

Analysis and Interpretation

For a better understanding of research results in this field, it is important to keep in mind the meaning of certain key ideas and concepts. Some of the problems of interpretation and analysis in this type of research are, therefore, set forth briefly.

Definition of technological change

Technological change is defined broadly in the BLS studies as encompassing significant changes in processes and equipment, and product and services produced, and materials, fuels, and energy used. The term "automation," which is sometimes popularly used as a synonym for "technological change," designates, strictly speaking, a particular type of current development. It has been variously defined, for example, as "automatic operations," "the mechanization of sensory control and thought processes," and "a concern with production processes as a system."

While BLS studies have been concerned with developments in automation, particularly in anticipating long-term trends, they are not the only technological changes taking place that affect labor requirements and industrial relations. For example, new ways of generating power, piggybacking in transportation, use of synthetic materials in manufacturing, mechanized methods of material handling, and faster steelmaking processes are important technological developments, not usually covered by technical definitions of automation, but having significant manpower implications.

Impact of productivity

Since one of the principal consequences of technological change, so far as manpower utilization is concerned, is an increase in productivity (output per

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employee hour), special attention is given in BLS studies to analyzing changes in industrial productivity. Such trend analysis is a useful method of measuring the pace of technological change. Changes in productivity, however, also reflect changes in capacity utilization and many other nontechnical factors. It is important to recognize that the productivity trend is only a partial measure of the rate of technological change.

In determining the impact of a specific technology, BLS studies try to indicate the reduction in unit labor requirements that the new process is designed to achieve. In some cases, estimates of labor savings are derived on the basis of comparisons with the estimated average technology of the industry under study; in others, with the best equipment that is available; or in actual plant studies, with the technology that is actually displaced.

It is also important to distinguish between the impact on productivity of the operation directly affected and on productivity of the plant as a whole. An advanced machine tool, for example, may result in a relatively large reduction in unit labor requirements in the machining opeations, but would have little impact on finishing and assembling, and may even require additional labor in engineering and maintenance work. The impact of plant productivity, therefore, would be considerably less than the effect on productivity of any department or operation directly affected.

Impact on employment

In assessing the impact of technological change on employment, it is necessary to consider the implications of plant manpower policies and the effects of economic changes, with which technological changes interact. Analysis of the impact of technological change purely in terms of machinery is incomplete.

At the plant level, for example, the substitution of machinery for labor may substantially reduce job opportunities in operations directly affected. If efforts are made, however, to eliminate these jobs by not filling vacancies created by quits, deaths, and retirement of employees, or by transfer of affected workers to other positions in the plant or office, labor savings could be achieved without displacing the workers affected.

Moreover, the employment impact of technological change is also interrelated with the effects of the business cycle. Thus, workers whose jobs are eliminated by technological changes may not be displaced from a plant until a decline in demand results in layoffs—a long time after the change has been made in some cases. In the subsequent recovery, however, they may not be hired back because their jobs no longer exist.

Since many changes exert their effects on employment through the competitive market, the employment trend for the industry as a whole must also be examined. The plant which reduces its unit costs through technological improvement may be able to gain a larger share of the market and increase its employment, but at the expense of the less technically advanced competing plants, which may be forced to shut down, displacing workers far from the location of the change.

Because of the whole complex of economic factors that operate through the market, including changes in demand, location, foreign competition, corporate organization, and consumer taste, it is very difficult to isolate the expanding and displacing effects of technological change.

Impact of occupations

Two aspects of occupational change resulting from technological changes are examined. Changes in job structure—the distribution of the plant or office work force by function or broad skill grouping—are studied to determine the extent of upgrading or downgrading. Since the content of jobs may be altered as a result of changes in equipment or processes, attention also is directed to intensive before-and-after analysis of job duties and the knowledge and abilities required to perform these duties as indicated by job descriptions and observation. The content of newly created jobs also is studied and the qualifications required and personal characteristics of individuals selected for these new positions are described, so far as possible.

Adjustment to technological change

Technological change has important implications for personnel management and collective bargaining within plants. The introduction of new machinery, products, or processes often requires movement of workers among jobs within the plant or office by transfer or promotion, the setting of wage rates, and selection of persons for new jobs. Often the adjustment proceeds according to rules established in advance through collective bargaining. Provisions to assist workers whose jobs are eliminated include severance pay, retraining, and early retirement. Besides analyzing the operation of formal provisions under collective bargaining, Bureau studies describe informal efforts to provide training, to utilize attrition, and to obtain jobs for displaced workers elsewhere. The limitations of these measures as well as their advantages are important matters studied.

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Impact of new electronic technology

RICHARD W. RICHE

The steady stream of technological progress that has characterized our society in America has resulted in higher productivity, elimination of many menial and dangerous jobs, higher wages and shorter hours, and a continuous flow of new products and services which have resulted in a higher standard of living. New industries employing thousands of workers have been formed to manufacture computers, electronic products, and technologies to provide energy and control the environment.

To be sure, innovation in industries such as longshoring, agriculture, and printing, to name a few, has eliminated jobs and required workers to acquire the unfamiliar skills associated with new technology. For some, the adjustment has been painful. But on balance, there is general agreement that the benefits of new technology far outweigh the disadvantages, and that innovation has led to economic progress, new job opportunities, and a more prosperous society.

At this point, early in the decade of the 1980's, there is widespread agreement that the pace of diffusion of technologies which incorporate advanced electronics will be accelerated over the next few years. The experience in the United States suggests that as long as the economy is growing, the introduction of innovations with potential for productivity gains can be compatible with rising employment. When computers were first introduced for office data applications, for example, frequently predictions were made that large numbers of clerical and kindred workers would be displaced and that job opportunities for millions would be curtailed. What actually did happen was quite different. In 1960, clerical workers in the United States numbered about 10 million and accounted for about 15 percent of total employment. By 1980, there were more than 18 million clerical workers and they accounted for about 19 percent of the total. Thus, instead of decreasing as had been predicted, clerical employment increased about 85 percent. And, it is projected to grow significantly to 1990.

Why did clerical employment increase instead of decreasing as predicted? First, normal growth in the volume of clerical work exceeded jobs eliminated by the computer. Second, computers made possible work that was previously impractical because it would have been too costly and too time consuming. Using computers, managers can now prepare reports and analyses that previously were desirable but too costly.

In addition to creating employment by expanding the scope of activities for many industries, the computer required new occupations such as systems analysts, programmers, keypunch operators, console operators, and tape librarians. And new industries were established to manufacture computers and related equipment, creating a variety of occupations and employing thousands.

Technological change can cause job displacement, especially when the industry is concentrated in a particular region or locality. Sometimes the employment impact is direct, as in the case of agriculture. In most cases, however, the effect is less obvious. Output does not advance at the same rate as productivity in all industries or plants, and consequently some industries register employment declines while others register increases. Regardless of the reason, displacements are costly for both the individual and the Nation.

This report examines four major technological changes under way in the United States and discusses prospects for their further diffusion. The four areas are microelectronics, industrial robots, telecommunications, and office automation.

The development of *microprocessors and microcomputers* in the early 1970's, and their widespread diffusion as we enter the 1980's, is a major innovation in electronics. Over the past three decades, the transistor that replaced the bulky vacuum tube was a first step in the development of miniaturized semiconductor integrated circuits which provide more power and reliability in a significantly smaller package. A microprocessor unit contains thousands of electronic components and complex circuits on a silicon chip less than one centimeter square. The unit can be combined with memory and input-output capability to build a microcomputer.

The use of microelectronics has had a significant impact on American consumers, workers, and manufacturing operations. A vast array of products—calculators, digital watches, video games, TV sets, and microwave ovens, to name a few—incorporate microprocessors and microcomputers. But behind the scenes in American manufacturing plants, production technologies and manufacturing methods are undergoing equally dramatic changes. Microelectronics are being incorporated in systems which control key production equipment, such as industrial robots and numerically-controlled machine tools. Moreover, microelectronic devices increase the processing capability of word processors, computers, data transmission and copying devices, automatic checkout counters, and other such equipmer

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used by banks, insurance companies, and retail and wholesale establishments.

The *industrial robot* is a second major technological innovation capturing current attention. The Robot Institute of America defines a robot as "a reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." According to the institute, about 4,000 robots are in use in U.S. establishments, with a large share in automobile manufacturing plants. They perform tasks such as material transfer, die casting, spot welding, spray painting, and limited assembly. Although U.S. industry is increasing its use of robots, Japan leads the world in robot use with more than triple the number of installations in the United States.

There is little information on the impact of robots on productivity and employment. However, evidence suggests that, following installation of robots, productivity is increased, unit labor requirements frequently are lowered, and quality control is improved. At one large manufacturer of refrigerators, for example, a robot sprays paint on refrigerator liners twice as fast as the two-person crew that it replaced.[1] The future impact of robots on productivity and employment will depend on the extent of development and diffusion of new generations of robots that can "see and feel."

Technological changes in *telecommunications* are underway in all major segments of the industry. These innovations are boosting productivity and changing the type of labor required in the two basic processes of telephone communication—call switching and signal transmission. The electronic computer is used extensively in both processes, as well as in other operational tasks and in management and accounting functions.

In call switching, electronic switching systems use high speed computers to handle local and long-distance calls. A growing share of calls is handled by electronic switching systems; total conversion is anticipated by the year 2000. These systems can handle three to four times more calls than electromechanical systems.

Sharp gains in long-distance volume have led to two innovative and important technologies in signal transmission—the millimeter waveguide and fiber optic cables. Both have far greater call-handling capabilities than the existing coaxial cables and microwave relays. The millimeter waveguide is essentially an underground tube through which signal-carrying waves are transmitted. It is designed for use on high density communication routes. Currently, this technology is being tested; future diffusion will depend on call volume growth.

Fiber optic cables for signal transmission are expected to become a major transmission medium in the 1980's. In this technology, glass fiber cables are combined with semiconductor light sources for very high capacity transmission. The fiber cables are compact, resist electrical interference, and interface well with digital switching and transmission techniques.

Other major changes anticipated for the telecommunications industry include further expansion of satellite communication, digital transmission, computerized systems for maintenance and testing, and automation of switching and billing tasks. Experts also foresee nontraditional uses of the communications network for electronic funds transfer in banking, electronic postal service functions, and data systems for the home which will combine communications and data processing capabilities.

Office *data handling and communication* is a fourth area where major technological change has occurred. A large segment of the Nation's work force, including more than 18 million clerical workers, is engaged in producing and processing data. Historically, capital investment in the office has lagged that of other operations, with investment per office worker amounting to less than $2,000, compared with about $25,000 per factory worker.[2]

This "investment gap" may be closed in the years ahead. Investment in office technologies will likely accelerate during the 1980's, as managers turn to modern data handling technologies to reduce labor, material, and related expenses. The largest share of office costs are deemed to be labor-related—a strong incentive for further mechanization.

Specific technologies to be diffused more widely include more powerful electronic computers; advanced model word processors; new equipment and techniques to store, retrieve, and transmit data on microfilm; and electronic mail networks. Increasingly, paper will be replaced by electronic images on a screen which can be transmitted by telecommunication methods.

General impact of innovations

Following are conclusions from the Bureau of Labor Statistics research on the implications of technological change for the work force.

- While all industries are experiencing technological change, the pace varies among and within industries. Each industry has its own story and it is not always in terms of computer technology and advanced automation. But even conventional changes, such as materials handling mechanization or the installation of larger capacity equipment or machines with faster speeds, are often major developments requiring workers to obtain new skills.
- The size of investment required, the rate of capacity utilization, and institutional arrangements are some of the factors that act as an "economic governor" on the speed of diffusion of technological change and, in turn, possible employment implications.
- Industries with greater application of technological advances generally experience larger increases in pro-

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ductivity (examples, air transportation and telephone communication); industries lagging in application of technological advances generally experience smaller or negative changes in productivity (examples, footwear and wood household furniture).

- The content of jobs and the qualities required of workers are being modified by technological changes. There is less demand for manual dexterity, physical strength for material handling, and for traditional craftsmanship. In contrast, employers are placing more emphasis on formal knowledge, precision, and perceptual aptitudes. As many manual tasks are mechanized, unskilled workers become monitors of very expensive equipment. The reduction in repetitive tasks that are so dissatisfying to the industrial worker may be welcomed, but the isolation and constant monitoring associated with advanced technology can create new stresses.
- Higher educational achievement of workers is becoming essential. The ability to read and write at a functional level is mandatory to interpret operating instructions of complex equipment, and to be retrained for the new skills demanded by changing technology.
- Many new occupations created by new technologies can be filled by retraining employees. Most retraining is accomplished in-plant and includes on-the-job and classroom instruction.
- In general, relatively few employees have been laid off because of technological change. This is due, in part, to the use of various techniques by the private sector to minimize adverse effects to the worker—techniques such as providing advance notice, retraining, and reassigning displaced employees to new jobs.

[1] "Robots Join the Labor Force," *Business Week,* June 9, 1980, pp. 62–76.

[2] Philip H. Dorn, "The Automated Office—The Road to Disaster?" *Datamation,* Nov. 15, 1978, pp. 154–62.

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Technology and Labor in Electrical and Electronic Equipment

Robert V. Critchlow

Summary

The pace of technological change has been uneven in the diverse group of industries that make up the electrical and electronic equipment group. The electronic components sector, for example, is a leader in technological innovation and has experienced strong growth in production, employment, and capital investment. The electrical machinery industries, however, are experiencing less rapid technological change. Production and employment growth also has been slower in these industries.

A number of occupations will be affected by technological change. Improvements in assembly procedures, primarily in the use of automatic equipment, including robots, are changing skill requirements and increasing productivity for several kinds of operatives. In the largest occupation—assemblers—work is shifting from manual assembly toward machine monitoring, loading, and maintenance tasks. The need for welders and painters may decline, while more mechanics and repairers may be needed. Engineers and technicians will make greater use of video terminals and computer techniques in designing machines and electronic circuits—which should improve their productivity and reduce the need for drafting employees. Solid-state controls, which are manufactured in this industry, will also be used in appliances and other products manufactured in this industry. They will increasingly replace mechanical controls (switches, timers, etc.) and bundles of electrical wires, which will increase the need for scientists, engineers, and technicians, while reducing the amount of manual assembly and soldering work required.

Production in the electrical and electronic equipment industry has grown steadily during the 1960–80 period. The electronic component sector has grown most rapidly, due to strong demand for integrated circuits and other semiconductors. Production has also increased in each of the other industries within this sector.

There is no BLS index of output per employee hour (productivity) for the broad industry group, but indexes are available for several individual industries. Productivity has increased, at varying rates, in each of the industries for which data are available. The household appliance industry experienced the highest rate of productivity growth. Productivity gains in these industries were most rapid during the earlier portion of the 1960–79 period.

Expenditures for plant and equipment have been increasing, with capital outlays highest for electronic components and communication equipment. Capital spending is expected to increase as those parts of the industry experiencing rapid technological development continue spending for new plant and equipment.

Employment rose at a relatively low annual rate of 1.6 percent between 1960 and 1980; the growth rate was highest in the early half of the period. Employment is projected to increase at an average annual rate of 1.7 to 2.5 percent between 1980 and 1990.

Technology in the 1980's

Technological changes are taking place in most sectors of the electrical and electronic equipment industry (SIC 36). To varying degrees, these changes will affect employment levels and occupational structures. Improvements in assembly operations include more automatic equipment to assemble printed circuit boards, and production lines with automatic stations to manufacture household appliances and television receivers. The trend toward more automated operations may lower unit labor requirements somewhat and shift job skills more toward machine monitoring and maintenance. Computer techniques are being developed to assist engineers in designing solid-state (semiconductor) electronic components and integrated circuits. Solid-state controls and switches, and printed circuits, important products of this industry, are replacing mechanical controls and electrical wires in household appliances, television and radio receivers, communication equipment, and other products made by this industry. Designing and installing solid-state controls generally require more engineers and technicians, and fewer assemblers, solderers, and machine operators than the older processes. Numerically controlled machine tools are achieving labor and other savings in turning out communication equipment and

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Table 3. Major technology changes in electrical and electronic equipment

Technology	Description	Labor implications	Diffusion
Equipment to design and fabricate semiconductors and related devices, including microprocessors	Computers and video display terminals can be used to design and lay out complex integrated circuits in less time than is necessary for older methods. This is especially applicable to microprocessors, which are among the most complex semiconductor devices. Fabrication of semiconductors is highly automated. Packaging the semiconductors after the fabrication step can be either very labor intensive or very automated, but the latter requires substantial capital investment.	Designing and fabricating semiconductors require relatively more scientists, technicians, and engineers and fewer assemblers and machine operators than the manufacture of electron tubes or mechanical switches and controls which they replace. Computer-assisted design (CAD) of semiconductors could reduce the demand for drafting employees, because engineers using CAD can do more of the design and layout work themselves, instead of delegating this work to drafters. If automated packaging technology becomes more widely used, it could reduce the demand for workers involved with manual packaging operations.	Computer-assisted design and automatic packaging equipment are in limited use due to their high cost. Highly automated fabrication equipment is standard.
Increased automation in assembly-line operations	Computer controlled automatic sequencing and inserting equipment for electronic components, along with a new assembly line where operators control the line speed while inserting components manually, are being put into use to manufacture television receivers. In the production of household appliances, larger capacity presses and a range of automatic assembly processes are being introduced, including limited applications of robots; and automatic equipment for some welding, fastening, material handling, and production operations.	New assembly technology generally lowers unit labor requirements and modifies job duties. New technology for assembly of appliances, for example, requires a higher proportion of worktime for equipment monitoring, machine feeding and loading, and maintenance. Manual tasks are reduced.	This TV assembly line is the first U.S. installation of a technology expected to be used more widely in the United States and already in general use in Japan. Most of the automated assembly equipment used in appliance manufacturing has been introduced in the last 5 years. Robots are likely to increase in use.
Numerically controlled machine tools	Numerically controlled machine tools are being used to turn out a wide range of products which are produced in small volume. In advanced systems, cutting sequences, machine speed, and other operations are controlled by a computer.	Unit labor requirements in machining operations are lower in numerical control, and skill requirements for machinists are modified. Operators monitor the machine tool operation rather than directly manipulate equipment, with programmer and maintenance workers skilled in electronics required in numerical control installations.	Nearly 5,000 numerically controlled machine tools were in use in the industry in 1978, with increased diffusion anticipated. The communication equipment and electrical industrial apparatus sectors of the industry lead in application of numerical control.
Advanced production equipment	Advanced equipment is being used to turn out several key products of the industry. For example, some portions of electric motors are now produced on automatic equipment, resulting in increased productivity. In the manufacture of automobile headlights, filaments are positioned more accurately and testing time reduced by use of new equipment. Household appliances can be painted on automatic lines, with the use of electrostatic painting technology. The electrostatic spray process uses either liquid or dry powder paint. An electrocoating process, in which metal parts are dipped into paint, is also used for high-volume finishing work on household appliances.	Advanced production technology generally reduces unit labor requirements. New electrostatic painting lines, for example, feature modern conveyor lines and little or no manual painting. Labor requirements are lower with dry powder paint than with liquid paint. Labor requirements are also low for electrocoating operations.	Electrostatic and electrocoating processes are in use in a number of plants.

other industry products. Electrodeposition painting technology is being used in household appliances, resulting in reduced labor requirements and materials costs. Table 3 provides a brief overview of the major technological changes taking place in this industry, their labor implications, and their expected diffusion.

Production of electronic components

Manufacturing electronic components (SIC 367) has traditionally been labor intensive, involving assemblers, machine operators, inspectors, and related occupations.[1] This industry's development of semiconductors since the mid-1960's has changed its production methods and labor requirements considerably. Semiconductor devices perform most functions of electron tubes (except cathode ray tubes), but are smaller, more reliable, and generally less expensive. As a result, semiconductor devices have replaced most electron tubes. The switch from manufacturing electron tubes to semiconductor devices requires more engineers, scientists, and technicians; and fewer assemblers and operators since many manufacturing operations are automated. The impact of this technology is marked. Employment in the part of the industry manufacturing electron tubes has declined

[1]Electronic components (SIC 367) consists of two major product groups. One group comprises all types of electron tubes: Television cathode ray picture tubes (SIC 3672), all other radio and television tubes (SIC 3671), and transmitting, industrial, and other special-purpose electron tubes (SIC 3673). The second group contains several products; the most important from the standpoint of technological and occupational changes are semiconductors and related devices (SIC 3674).

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steadily, while employment in the rest of the industry—including semiconductors—has risen sharply.

The first steps in fabricating a semiconductor device—circuit design and mask making—are complex and require high-level technology. Many months are needed to design a complex integrated circuit and to make photo masks from which the circuits will be produced. Design and layout involve determining which electronic components (transistors, resistors, etc.) are required to make the circuit perform as desired; then deciding how to arrange the circuit components in the circuit base material.

Conventional methods of circuit design and layout—drawing circuits by hand on graph paper and assembling "bread board" circuits for testing—are slow and require skilled scientists and technicians. Computer-assisted design (CAD) is faster, more accurate, and allows the designer flexibility in circuit design and layout. Developing a CAD system requires complex programming to store information in the computer and to display and position the simulated circuits on a cathode ray tube terminal. CAD is used by only a few manufacturers, since equipment and software costs are high and the system must be used intensively to be cost effective. But where it can be used, results can be dramatic: In some applications for thick-film integrated circuits, computer-aided design reduced costs by 300 percent.[2]

As CAD technology is diffused more widely, several occupations will be affected. Computer specialists will be needed for initial program set-up, but this could be a one-time operation for each CAD system. Drafters might be largely bypassed as engineers use video terminals for design and layout. Computer control may also be extended to photographic and mask-making operations, similar to automatic printing plate technology used in the graphic arts industry. This could reduce employment of technicians who presently do the photographic work in mask making.

Integrated circuit fabrication is a highly automated, batch-type process that can produce hundreds of separate, complete circuits in each production run. Silicon cylinders several feet long by several inches in diameter are sliced into thin wafers, loaded onto special trays, and put through production steps as a group. During production, many tiny circuits are fabricated, side by side, across the surface of each wafer.

Labor costs in integrated circuit fabrication are relatively low because of extensive automation. Most labor requirements are associated with loading and unloading the trays of wafers, and with operating fabricating and testing equipment.

After the wafer is cut into individual circuits, the tiny circuits are encased in protective packages. The packages are larger and stronger than the circuit dies, and contain the electrical connections needed for electronic appliances. In general, the packaging process involves bonding individual circuit dies onto metal stampings, then attaching very fine wires to make the electrical connections between the dies and the electrodes on the stampings. Plastic covers are then molded around the dies, sealing them inside the now-complete packages. Finally, each circuit is tested to insure proper operation.

Circuits are most commonly packaged manually, which is quite labor intensive. An alternative has been to use automated handling equipment, although high equipment costs have limited this option. However, since labor costs are rising and packaging technology is improving, use of automated equipment may increase.

Microelectronic technology

Microprocessors are a fairly recent development of semiconductor technology, and are of importance to the electronics industry both as a product sold to others and as a technology that can be applied to the industry's own design and production operations. A microprocessor contains a complete miniature processing unit on a single silicon chip. It can be combined with other chips containing memory, timer, and input-output functions to build a complete microcomputer system on a single circuit board. Designing and fabricating microprocessor chips is a very complex undertaking, but the range of applications is already substantial and is growing rapidly. The largest volume of microprocessors in use are low-powered 4-bit devices that provide relatively simple control functions. More powerful 8-bit devices, however, account for most of the revenue from sales related to microprocessors.

Microprocessor-based systems are expected to dramatically change the function and capabilities of household appliances during the 1980's. Estimates vary on the rate of diffusion of microelectronics in the appliance industry through the mid-1980's, but one industry source estimates that 50 percent of all major appliances will be controlled by microelectronic devices.[3]

One of the most popular applications of microcomputers will continue to be microwave ovens, where sophisticated controls allow a wide range of cooking sequences and temperatures (including ovens that can be programmed by the user). Microcomputers also are being used in cooking ranges, dishwashers, clothes washers and dryers, and other household appliances.

The growing application of microelectronics to industrial and household appliance controls has brought about changes in design and production operations. Mechanical engineers and industrial designers work more closely with electrical engineers to develop electronic controls as substitutes for mechanical and electromechanical con-

[2]"Hybrid-circuit Technology Keeps Rolling Along," *Electronics*, July 22, 1976, p. 104.

[3]Donald L. Owens, "Microelectronics: A New Horizon for Appliances," *Appliance*, July 1979, pp. 28-31.

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trols. Assembly operations and labor requirements change when solid-state controls are used. It is no longer necessary, for instance, to route and solder large numbers of individual wires into place; thus fewer solderers are needed. Also, flat electrical cables and flexible printed circuits with plug-in connectors are replacing bundles of separate wires. There may be a secondary impact in that fewer components and less equipment are needed to produce electronic controls. This could reduce the labor needed for stock control, material handling, warehousing, and transportation.

Improvements in assembly technology

Many types of assembly operations take place in the diverse group of industries that make up the electrical and electronic equipment industry. Technological innovations in assembly include increased automation and improved manual assembly lines for TV receiver producers and, in appliance manufacturing plants, automated assembly operations for household appliances and in-house assembly of printed circuit boards.

A major domestic TV manufacturer has begun operating a new assembly line that has increased productivity and product quality. This is the first such TV receiver assembly line in operation in the United States, although this type of assembly line has been used for several years in Japan with considerable success. The new line features both computer-controlled automatic sequencing and component inserting equipment, as well as new technology for inserting parts manually, and is achieving productivity gains. On the new line, solid-state components come packaged in reels from vendors. Only one type of component is included in each reel, and each reel may contain several hundred components. A number of these one-of-a-kind reels are mounted on a component sequencing machine which—under computer control—automatically removes individual components and deposits them on a conveyor in the sequence required for the automatic inserting machine. The conveyor transports each component through an automatic testing station to insure that it functions properly and is in the correct sequence. Finally, the components are automatically taped onto a new reel for use in the inserting machine, which automatically inserts components onto the circuit boards and then cuts and crimps the wire leads on each component to secure them to the board. Completed circuit boards are transported through an automated wave soldering machine that solders all electrical connections in one operation.

Most operators on the new line originally held assembly jobs involving manual insertion of components into circuit boards or manual assembly of parts onto the television chassis. When the automated equipment was brought into the plant, this group was retrained to load and operate the machines. The machine operator positions involve higher skill and pay levels.

Productivity is increased with the automatic sequencing and inserting equipment in that operators can insert more components per hour than is possible with the same number of people manually inserting components into circuit boards. Additionally, quality is improved since every component in the automatic line is tested before being inserted into the boards. A major feature of the new line is the specially designed assembly equipment for manually inserting components that cannot be handled on the automatic equipment.

In the manufacture of appliances, improved technology is being installed in major production tasks. Sheet-metal components are being fabricated by larger capacity presses fed directly from coils of sheet metal. These components are produced at high speeds with a minimum of manual handling.

New technology for high-volume assembly also is being introduced. Assembly tasks are labor intensive. When assembly lines become automated, unit labor requirements are lowered and job skills frequently shift to machine monitoring, machine feeding and unloading, and machine maintenance.

One manufacturer is using automatic assembly techniques to insert a retaining pin into the spout cap of a tea kettle, in place of a manually fastened screw-and-nut assembly. The automatic equipment has increased the assembly rate by 84 percent, lowered unit labor requirements, and decreased fastener costs.

Another appliance manufacturer has installed an automatic line to assemble washing machine cabinets that has a maximum output of 350 cabinets an hour. Sheet-metal blanks pass through presses that shape them into cabinets, which then move past automatic welding stations where gussets and brackets are attached. The cabinets next are transported by conveyor through a manned inspection station and then to the finishing area.

The entire line is staffed by three operators and one inspector, who checks cabinets as they come off the line. In a less mechanized, conventional system with the same volume of output, labor requirements would be higher. A solid-state control system with a cathode ray tube (CRT) display terminal provides data on malfunctions and defects which facilitate repairs. The automatic assembly line has increased output by 40 percent, raised cabinet quality, and improved operator safety.[4]

Robots are being used in several assembly applications by one large manufacturer of appliances to cut costs and improve productivity. In one application, two robots are used to load and unload a press that trims plastic liners used in refrigerators. In another application elsewhere on the assembly line, two more robots spray the interiors of the refrigerator cabinets with an adhesive that holds a layer of foam insulation; each robot takes the place of two

[4]James Stevens, "A New Cabinet Line Pays off for Maytag," *Appliance*, February 1976, pp. 34-35.

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workers and there is a 10-percent reduction in the amount of adhesive material used.[5]

One manufacturer recently built a highly mechanized assembly line for energy-saving refrigerators that speeds production and testing procedures, and reduces labor requirements for machine operators, welders, and material handlers. The cabinets are produced on a semiautomatic line that includes an automatic destacker (which transfers metal cabinet blanks onto the production line) and an automatic electric resistance welding station. Serpentines –the metal tubes that carry freon inside refrigerators—are made in an off-line operation. Coils of metal tubing are fed into a machine that automatically straightens the tubing, then cuts and bends it into the proper dimensions for installation in refrigerators. Solid-state controls give flexibility in programming the equipment to make serpentines of varied sizes.

Foam insulation is injected into the cabinets on a 6-station automatic foaming installation that utilizes solid-state controls. Only one person is needed to operate this equipment. Cabinets are brought by conveyor belt, where a system of photo cells and magnetic tape readers routes the cabinets—via a turntable and runout conveyors—to the proper foaming station. The cabinets are automatically positioned on the foaming fixtures, filled with insulation, and lowered onto another conveyor to leave the foaming operation.[6]

Appliance manufacturers have begun to assemble their own printed circuit boards instead of purchasing them from electronic component suppliers. Thus, technology and labor are "transferred" from one sector of the electrical and electronic equipment industry to another. The assembly of printed circuit (PC) boards involves inserting resistors, capacitors, integrated circuit (IC) chips, and other components onto the boards, soldering all connections, then cleaning and inspecting the completed boards. Assembly methods range from largely manual tasks—the predominant method at this time—to semiautomatic and fully automatic processes. There are several "aided manual" systems that allow relatively unskilled operators to assemble complete PC boards. One of these systems, for example, positions the PC board in a machine which guides the operator through a sequence of production steps by illuminating the appropriate holes in the PC board into which each succeeding component is to be inserted. At the same time, a tray of parts is positioned so that only the proper component is accessible to the operator. If the more automatic processes become more prominent, the employment of assemblers will be affected.

Numerically controlled machine tools

Numerically controlled machine tools are being used increasingly in the electrical and electronic equipment industry. They are used most extensively in the communication equipment and electrical industrial apparatus sectors of the industry to turn out a wide range of products which are produced in small volume. More than 1,000 numerically controlled machine tools are being used in each of these two major sectors.[7] In advanced numerical control systems, cutting sequences, machine speed, and other operations are controlled by a computer with significant savings in unit labor requirements, tooling costs, and lead time. The function of the machine operator has changed from direct manual manipulation of equipment to monitoring the operation of the machine tool and loading and unloading parts. A programmer—a new position –develops the sequence of operations, tools to be used, and feed and speeds of the machine tool. Maintenance workers with a knowledge of electronics are needed to service numerical control systems. The outlook is for further advances in numerical control technology including its use for inspection of parts.

Advanced production equipment

Other production processes where new technology is being used include the manufacture of portions of electric motors, testing of automobile headlamps, and painting of household appliances.

Automated stator production. Automated equipment is being used to manufacture stators for electric motors. Automatic presses stamp out selected parts, insulation is inserted automatically into the stator core, and coils are wound and inserted automatically. The new equipment has considerably increased line speed, increasing the output without increasing the work force.

Automobile headlamp testing. Photometric equipment that evaluates and records headlamp performance automatically is helping manufacturers test headlamps to ensure they meet specifications set by the Federal Government. The time required to test headlamps has declined from 20 minutes to less than 5 minutes, with sophisticated optical equipment available to position headlamp filaments to close tolerance, thus increasing worker output and productivity.

Advanced painting technology. New technology for the electrical depositing of paint onto household appliances is being introduced more widely. In electrostatic painting, paint particles are electrically charged and sprayed onto surfaces carrying an opposite electric charge to form a strong bond. The painted surface is then baked to a hard finish. The electrostatic process can be used with liquid or "wet" paint or the increasingly popular dry powder paint.

[5]"Robots Join the Labor Force," *Business Week*, June 9, 1980, p. 68.

[6]Gene Morgan, "A Sophisticated System Speeds Production," *Appliance*, September 1977, pp. 50 52.

[7]"The 12th American Machinist Inventory of Metalworking Equipment 1976 78," *American Machinist*, December 1978.

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Labor requirements in the new electrostatic systems are lowered since material handling and painting tasks are largely automatic; robots are used in some installations. At one plant manufacturing household appliances, an operator manning a control console on a newly installed wet painting electrostatic line can change paint colors in 60 seconds. Quality of painting is improved and maintenance costs are lowered.

Dry powder paint, used in the electrostatic process, is expected to be employed more widely during the 1980's. Dry powder painting systems require fewer operators than liquid or "wet" systems since paint mixing is eliminated and manual touch-up is reduced. Other factors favorable to further diffusion include easier paint handling and clean-up operations. Energy requirements also are lower. One firm which replaced a wet system with a porcelain enamel powder system reported labor costs were lower by 33 percent, rejects and materials were reduced by 50 percent, and quality was improved.[8] A disadvantage is the inability of dry painting systems to handle frequent color changes. In 1976, nearly 40 electrostatic thin-film powder spraying systems for appliances were in use. Additional installations are forecast for the 1980's.[9]

Another form of electrodeposition—electrocoating—involves immersing a metal part into a tank of coating material. The metal and the liquid in the tank carry opposite electrical charges, which form the bond, providing a continuous, evenly deposited film on the metal part. This process was introduced for high-volume finishing operations in the mid-1960's, and has since gained wide acceptance, especially for applying primer coats on appliances. The process is less labor intensive than conventional painting processes, gives a uniform coating even on intricately shaped objects that have hidden or recessed areas, minimizes material costs because there is almost no wasted paint, and causes much less air and water pollution.[10]

Output and Productivity Outlook

Output

The electrical and electronic equipment industry turns out a variety of products for government, industry, and consumer use. This product diversity is shown in table 4, which presents output growth in major industry sectors.

Output in the industry as a whole has increased at a relatively high annual rate. According to the Federal Reserve Board production index for this industry, output grew steadily from 1960 through 1980, averaging a growth rate of 5.9 percent a year. As shown in table 4, the rate of growth in output was substantially higher during 1960–67 than in 1967–80. There was a slight dip in output during 1970 and 1971, after which output climbed to a peak in 1974, dropped rather abruptly in 1975, and then rose sharply in 1976 through 1980.

Table 4. Output growth in electrical and electronic equipment, 1960–80

SIC	Industry sector	Average annual percent change[1]		
		1960–80	1960–67	1967–80
36	Total electrical and electronic equipment[2]	5.9	10.5	4.2
361,2	Electrical equipment and parts	4.2	8.1	2.8
363	Household appliances	4.6	8.7	2.5
365	Radio and TV receiving equipment	3.3	13.8	.6
366	Communication equipment	3.8	7.0	2.7
367	Electronic components	12.5	22.0	8.8
369	Miscellaneous electrical equipment	5.5	7.2	5.0

[1] Least squares trend method.
[2] Includes data for SIC 364, electric lighting and wiring equipment, not available separately.

SOURCE: Board of Governors of the Federal Reserve System.

Output in the electronic components industry (electron tubes, semiconductors, integrated circuits, etc.) has grown more rapidly than in any other industry in the group, increasing at an average annual rate of 12.5 percent during 1960–80, more than double the annual growth rate for total electrical and electronic equipment over the same period. Most of this expansion in output has been in integrated circuits—which include microprocessors, introduced in the mid-1970's and gaining widespread acceptance. Passive components (such as capacitors, resistors, and connectors) and discrete semiconductors have made lesser contributions.

Output of electron tubes was fairly stable during the 1970's; the decline in production of receiving tubes (as solid-state components became more widely used) was offset by slight gains in TV picture and specific-purpose tubes.

Output growth was slowest in radio and TV and communication equipment. Consumer discretionary income and imports affect the level and growth of output in the radio and TV industry—which includes a number of consumer electronic components in addition to radio and TV receivers. In communication equipment, telephone and telegraph products account for almost one-third of the value of industry shipments. The remaining two-thirds consist of electronic systems and equipment for which the U.S. Government is the major purchaser—especially the Departments of Defense and Transportation, and the National Aeronautics and Space Administration. Output growth, therefore, depends heavily upon

[8] "Plant Experiences with Porcelain Enamel Powders," *Appliance*, November 1978, pp. 49, 67.

[9] Gene Morgan, "Focus: Powder Coating," *Appliance*, September 1976, pp. 45–49.

[10] Gene Morgan, "Electrocoating," *Appliance*, November 1978, pp. 39–41.

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the demand from new households, business communication needs, and Federal Government procurement policies.

The expansion of output in the major sectors of the electrical and electronic equipment industry will continue to depend on several factors. In electronic components, for example, the growing commercial diffusion of a relatively new product, microprocessors (a complex integrated circuit finding application throughout the economy in a growing number of products from games to industrial robots), will require further expansion of production facilities. In electrical equipment, demand for electric transformers and switchgear depends heavily upon residential, commercial, and industrial construction. In major household appliances, population growth, family starts, and housing construction influence final demand.

Table 5. Output per employee hour in selected electrical and electronic equipment industries, 1960-79

SIC	Industry	Output per employee hour		
		Average annual percent change		
		1960-79	1960-67	1967-79
3621	Motors and generators	2.1	5.6	1.2
3631,32, 33,39	Major household appliances	4.4	6.1	3.9
3641	Electric lamps	1.8	2.8	2.1
3645,46, 47,48	Lighting fixtures	[1]2.6	[2]2.9	[3]2.6
3651	Radio and TV receiving sets	3.9	6.0	3.4

[1] 1961-78.
[2] 1961-67.
[3] 1967-78.

SOURCE: Bureau of Labor Statistics.

Productivity

Although a productivity measure for total electrical and electronic equipment is not published by the BLS, the measures available for several of the individual industries indicate that productivity change varies significantly by industry, and that growth rates have slowed over the past decade.[11]

The rate of increase in output per employee hour in the industries for which BLS publishes measures ranged during 1960-79 from an annual rate of 1.8 percent in electric lamps to an annual rate of 4.4 percent in major household appliances (table 5). In household appliances, output grew more rapidly than employee hours during 1960-68; output continued to grow slowly and employee hours declined during 1969-79. In all five of the industries included in table 5, the rate of increase in output per employee hour was lower from 1967 to 1979 than from 1960 to 1967. The sharpest decline in productivity was in motors and generators.

The extent to which technology affected the movement of productivity cannot be measured precisely. In all five of these industries, and in others for which BLS measures are not available, new technology has reduced unit labor requirements in selected production operations. The anticipated higher levels of spending for new plant and equipment could contribute to further productivity gains in key production tasks.

Investment

Capital expenditures

The electrical and electronic equipment industry has invested substantial funds for capital improvements, including the latest production technologies discussed in this report. In 1976, expenditures for new plant and equipment totaled $1.7 billion (constant 1972 dollars), more than twice the $800 million invested in 1960.[12] Capital expenditures per production worker averaged $1,385 in 1976, well above the average of $803 in 1960.

The pace of capital spending has been uneven. Over the longer term 1960-76 period, expenditures for plant and equipment rose at an annual rate of 5.3 percent. Capital spending during 1960-67 increased at a substantially higher annual rate of 14.0 percent. In the 1967-76 period, however, during which expenditures fluctuated markedly, outlays (in constant dollars) declined by an average annual rate of 0.2 percent. Between 1973 and 1976, the decline averaged 7.8 percent a year.

Capital spending also varied significantly among the individual industries which make up the total electrical and electronic equipment industry. The electronic components industry led all industries in the group with $478 million spent for new plant and equipment in 1976. Expenditures in communication equipment were the second highest, $399 million in 1976. Combined, these two industries were the source of more than one-half of capital spending.

Research and development

The electrical and electronic equipment industry is a leader in research and development (R&D) spending. According to the National Science Foundation, R&D expenditures by the electrical and electronic equipment

[11] Productivity measures are published by the BLS for the following five industries: Motors and generators (SIC 3621); major household appliances (SIC 3631, 32, 33, and 39); radio and TV receiving sets (SIC 3651); electric lamps (SIC 3641); and lighting fixtures (SIC 3645, 46, 47, 48). See *Productivity Measures for Selected Industries, 1954-79*, Bulletin 2093 (1981).

[12] Capital expenditures data are from unpublished, deflated total annual investment series developed in the BLS Office of Economic Growth and Employment Projections. See *Capital Stock Estimates for Input-Output Industries: Methods and Data*, Bulletin 2034 (1979). Expenditures for 1976 are the latest available.

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industry totaled $7.6 billion in 1979, up from the $2.9 billion allocated in 1963.[13] In 1979, this industry ranked second only to aircraft and missiles in total funds allocated to R&D. Federal Government R&D funds accounted for 42 percent of the $7.6 billion spent in 1979, and company funds, 58 percent. Since 1973, company funds for R&D in electrical machinery and communications have exceeded Federal Government R&D funds.

The electrical and electronic equipment and communication industries employed 94,700 R&D scientists and engineers (full-time equivalent) in 1980, leading all other major industry groups for which the National Science Foundation provides data.

Employment and Occupational Trends

Employment

The industry employed slightly over 2.1 million workers in 1980 compared to 1.4 million in 1960—a 1.6-percent annual growth rate (chart 9). More than one-half of the industry work force in 1980 was engaged in manufacturing communication equipment and electronic components.

The trend in employment, as in other measures for this group of industries, varied among the major industry sectors (table 6). Employment in electronic components increased at the greatest annual rate (3.4 percent) during 1960–80, a period of generally strong demand for these products, particularly integrated circuits (which include microprocessors). The average annual employment growth rate has been slowest in electric transmission and distribution equipment and radio and TV receiving equipment. Employment in these industries increased during the 1960's, then declined during the 1970's, so that by 1980 the level was about the same as in 1960.

Employment growth in the electrical and electronic equipment industry was highest during 1960–67, compared to the more recent 1967–80 period. As indicated in chart 9, employment increased at an annual rate of 4.1 percent during 1960–67, compared to an annual rate of 0.6 percent during 1967–80. Employment dropped sharply (by about 14 percent) between 1974 and 1975 as demand slackened. This pattern of employment growth—a higher rate during the earlier of the two periods discussed in this report, followed by a lower growth rate or a decline in employment during the latter portion—was experienced in all industry sectors except miscellaneous electrical supplies.

[13] These are current-dollar data; the increase in real terms is not as great. Before 1978, the National Science Foundation published R&D expenditure data for both electrical and electronic equipment (SIC 36) and communications (SIC 48) as one combined figure. Very little R&D work is done in SIC 48. It is largely a service industry that uses equipment developed and manufactured in SIC 36. Beginning in 1978, R&D data for the two industries are published separately.

Table 6. Average annual rates of change in employment, electrical and electronic equipment, 1960–80

SIC	Industry sector	Average annual percent change[1] (all employees)		
		1960–80	1960–67	1967–80
36	Total electrical and electronic equipment	1.6	4.1	0.6
361	Electrical transmission and distribution equipment	.1	2.3	-1.6
362	Electrical industrial apparatus	1.7	3.0	1.1
363	Household appliances	.8	2.5	-.3
364	Electrical lighting and wiring equipment	2.2	6.3	.6
365	Radio and TV receiving equipment	.0	6.8	-2.6
366	Communication equipment	.7	3.0	-.5
367	Electronic components	3.4	7.8	2.4
369	Miscellaneous electrical equipment	2.9	1.0	3.3

[1] Based on least squares trend method.

SOURCE: Bureau of Labor Statistics.

The outlook is for employment in this group of industries to increase at an average annual rate of 1.7 to 2.5 percent between 1980 and 1990, according to BLS projections based on three versions of economic growth.[14]

Occupations

The structure of occupations is expected to undergo change. As shown in chart 10, all the major occupational groups except sales workers are expected to increase between 1978 and 1990.

Operatives, the largest occupational group in the industry, accounting for about 45 percent of total employment in 1978, are projected to increase by more than one-fourth between 1978 and 1990. They will continue to be by far the largest occupational group (47 percent of total employment in 1990). Assemblers make

[14] Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy, developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On chart 9, level A is the low trend, level B is high-trend I, and level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review*.

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up more than one-third of the operatives; they are expected to increase in number at a slightly higher rate than the average for all occupations in the industry. Although new technologies applicable to assembly operations will be diffused more widely, assembly of household appliances and other products is expected to continue to involve a high degree of manual tasks. In some assembly operations, however, manual tasks are expected to decline and job skills increasingly will involve more equipment monitoring, machine feeding and unloading, and equipment maintenance. In contrast to assemblers, employment of solderers is expected to decline by 30 percent and welders and flamecutters by 8 percent between 1978 and 1990 as automated equipment is diffused more widely. In craft occupations, employment of mechanics, repairers, and installers is expected to increase sharply as mechanization of production operations continues in the 1980's.

The rate of employment change in the major occupational categories presented in chart 10 is expected to vary among the industry sectors. Thus it is useful to examine BLS occupational projections for three industry groups: Household appliances (SIC 363); radio and TV and communication equipment (SIC 365,6); and a miscellaneous group that covers SIC 361, 2, 4, 7, and 9.

Less change in the composition of occupations is expected in the radio, TV, and communication equipment group than in the others. Employment of operatives, who account for more than one-third of the employees in this industry group, is expected to increase by about 12 percent between 1978 and 1990. However, fewer solderers will be needed. Professional and technical workers are expected to increase at a greater rate, while sales workers, service workers, and clerical workers are projected to decline.

Strong employment growth is expected in household appliances—numerically the smallest of the three industry groups. Sales workers is the only major occupational group in which a decline is expected. Professional and technical workers should increase, although at a lower rate than the other occupational groups.

Employment in all occupations except sales workers is expected to grow in the miscellaneous group. Large increases are expected for managers, clerical workers, craft workers, operatives, and laborers. Professional and technical workers and service workers should experience smaller employment increases.

Adjustment of workers to technological change

Although new technology is not expected to result in major displacement, some collective bargaining contracts in the electrical and electronic equipment industry contain specific provisions concerning technological change. One such agreement requires that the company provide the union (the International Brotherhood of Electrical Workers) with at least 4 weeks' advance notice before installing numerical-control or computer-control equipment that will displace employees. The contract also requires that, where reasonable and practicable, the company will retrain displaced employees in order of seniority. The Communications Workers of America (CWA) and the International Brotherhood of Electrical Workers both have contracts with one large firm that contain a clause providing early retirement, under certain conditions, for workers displaced by technological change. A CWA contract recently negotiated with a large employer contains provisions for a joint labor-management Technological Change Committee to establish methods to avoid adverse impacts of technological change on the work force. The CWA contract also provides protection for employees downgraded because of technological change.

Where no specific provision relating to technological change is included in the contract, general provisions pertaining to seniority, retirement, training, supplemental unemployment benefits, and related topics can facilitate adjustment of employees to the requirements of new technology. About two-thirds of the industry's production workers are estimated to be unionized. The major unions, all AFL-CIO affiliates, are the International Brotherhood of Electrical Workers; the International Union of Electrical, Radio and Machine Workers; and the Communications Workers of America.

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Technology and Labor in Electric and Gas Utilities

Robert V. Critchlow

Summary

Technological changes in the electric power and gas industry continue to lower labor requirements in some occupations and raise productivity. Major innovations underway include the more widespread use of computers to assist generating plant control room operators in logging data, monitoring equipment, and performing calculations; an increase in the number of nuclear power stations, which generally require a more highly skilled work force than conventional plants of similar capacity; and the return to coal as a major fuel source. The development of highly mechanized vehicles for power line construction and repair has changed the size and occupational makeup of power line work crews. The more widespread use of extra-high-voltage transmission also has brought about changes in power line repair techniques.

Capital expenditures have increased considerably since 1960, reaching a level of $25.8 billion in 1977. (In real terms, however, the increase is not this great because the price of new plant and equipment has increased.) Electric utility companies account for most of the industry's expenditures—about 84 percent in 1977. Capital spending is expected to increase fairly steadily over the next decade. Electric utilities cancelled or postponed part of their planned capital expenditures for 1974 and 1975 for a combination of reasons, including unfavorable economic conditions, forecast reductions in demand, and problems with regulatory and environmental concerns, but expenditures rose again in 1976 and 1977.

Output per all-employee hour increased at an average annual rate of 4.6 percent from 1960 to 1977, with the most rapid increase occurring between 1960 and 1967. Due in part to technological changes, labor requirements for operating and maintenance employees in electric generating plants have declined since 1960, and are lower per kilowatt of capacity for large plants than for small plants. Employment grew at the rather slow rate of 1.2 percent a year between 1960 and 1977, reaching a peak of 684,200 workers in 1974 and declining to 673,000 in 1977. Employment is expected to continue to increase at an average rate of 0.7 percent a year between 1977 and 1985. Occupational requirements may change somewhat in response to changes in the size of electric generating plants and the type of fuel used: Nuclear plants, for instance, will require a larger proportion of scientists, engineers, technicians, and security staff compared to fossil-fuel plants. The construction and maintenance of nuclear power plants require highly skilled welders and other craft workers. Some concern exists that possible labor shortages in some craft and technical occupations could delay construction of nuclear generating plants, and, if exhaust gas scrubbers become mandatory on coal-fired plants, the number of engineers, technicians, and maintenance personnel could increase substantially.

Technology in the 1970's

Major technological changes are taking place in the electric power and gas industry which directly affect the industry's work force and productivity. These include the more widespread use of electronic computers, nuclear power generation, and coal as a major fuel for electric generating plants. Extra-high-voltage transmission will continue to make possible the economical transmission of large quantities of electric power. In constructing and maintaining transmission lines, labor requirements are being reduced through the more efficient utilization of skilled workers and fleets of mechanized vehicles by computerized scheduling of work assignments. The mechanized fleets, however, require an increase in vehicle maintenance crews. Innovations such as process control computers, being introduced in an already highly instrumented environment, will have a less extensive impact on employment and occupations than such changes as nuclear power installations, which require substantially more scientific and technical staff than conventional installations of similar capacity. Research now underway on coal liquefaction and gasification processes may ultimately provide a clean-burning fuel from an abundant energy source to replace oil and natural gas.

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Electronic computers

Computers are used extensively in the utilities industry. In addition to their now commonplace use in business operations, computers are being applied to generating plant operations, control over transmission systems, and scheduling of work assignments for line crews.

Process control computers in generating plants provide assistance to control room operators in start-up operations, data logging, monitoring, and performance calculations, and they are becoming standard equipment in new plants and in many older large plants. Of the plants sampled in a recent survey, nearly 76 percent used automatic data collection for computerized performance calculations, and 24 percent had computers with control-function capacity.[1] Fuel savings, increased safety and reliability, reduced chance of operating errors leading to equipment damage, and improvements in equipment utilization are claimed. Many large plants have operations that are so complex that a substantial amount of automatic control is required for safety and reliability.

Process control computers are commonly applied to economic dispatch and automatic load control—operations principally concerned with dispatching power over transmission lines and the coordination of power generation and interchange. These operations have become so complex that dispatching personnel have difficulty assimilating the vast amount of data available. The solution has been the development of automatic control systems typically consisting of digital computers, local and remote cathode ray tube (CRT) terminals, animated diagram boards, and a network of telemetering devices. These systems provide dispatchers with the information and control necessary to supply power economically at proper voltage and frequency throughout the power system. The optimization of power production, continuous control of generating units, and improved reliability and accuracy of the system provide direct economic benefits. Indirect benefits include the improved coordination of loads between interconnected utilities.

There are some applications of process control computers to full closed-loop control of generating plants—although this is generally limited to hydroelectric stations. In one such application, a 4-unit 285-megawatt (Mw) hydroelectric plant can be operated automatically, either locally or by remote control from a central dispatching center. In another application, a 4-unit 225-Mw hydro plant is controlled from a location 8 miles away; the only personnel at the plant are security guards. The extent to which closed-loop remote control of generating plants is used is not known, but, where used, it allows some reduction in operating personnel.

Computers can be applied to a number of other operations, such as plant design, long- and short-term planning, fossil-fuel scheduling, and nuclear core analysis. The range of computer applications will probably grow in the future as computer hardware and software technology continues to develop.

Many of the computer applications require the use of sophisticated mathematical models and techniques —which, in turn, require programmers, systems analysts, peripheral-equipment operators, and others in computer-related occupations. The demand for people with computer-related job skills should increase along with the increasing range of computer applications. Also, utility engineers must have training in computer techniques to use computers for transmission and distribution (T&D) systems planning and for studies of T&D operations.

Computers are also being used more widely to schedule line crews with highly mechanized vehicles to reduce time and cost in constructing and maintaining transmission and distribution lines.

Nuclear power

Nuclear generation of electric power has become increasingly important over the past several years as costs of commercial power generation have risen and as concern has mounted over the future availability of petroleum. Problems associated with air pollution caused by conventional power plants also have been a factor. By the end of 1977, 49 licensed nuclear plants were in operation, with 49,881 Mw, or 9.0 percent of total generating capacity.[2] The Federal Energy Regulatory Commission has estimated that, by 1985, nuclear power plants may account for 18.6 percent of total generating capacity.[3]

The increase in the number of completed nuclear power plants over the past several years has been less than anticipated. Inflation, combined with tight money markets and uncertainty as to future demand growth, has caused postponements and cancellations in the construction of a number of nuclear plants. Opposition to nuclear power plants based on concern over safety and environmental factors, nuclear fuel reprocessing, and waste disposal also has caused delays and cancellations. In addition, the lead time for bringing a nuclear plant on line has increased as a result of the growing complexity and size of the plants themselves, changing Federal regulations concerning construction and operation procedures, and problems in finding suitable sites. In late

[1] Gordon D. Friedlander, "20th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1977, p. 51.

[2] *Monthly Power Plant Reports*, FPC Form 4, U.S. Department of Energy, 1977.

[3] Department of Energy estimates.

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Table 8. Major technology changes in electric and gas utilities

Technology	Description	Labor implications	Diffusion
Electronic computers	Process control computers in generating plants are used for data logging, monitoring, and performance calculations, providing fuel savings, increased safety and reliability, and improvements in equipment and labor utilization. Process control computers are commonly used in dispatching power over transmission lines and coordinating generating and interchange operations. Computer scheduling of labor and vehicles has reduced time and costs in maintenance and construction operations.	Reduces the time control room operators and system load dispatchers spend reading instruments, logging data, and performing calculations. Load dispatchers would have difficulty assimilating the amount of available data without computer assistance. Increased demand for people in computer-related occupations. Some utility engineers required to learn computer techniques.	Seventy-six percent of generating plants use automatic data collection for computerized performance calculations, and 24 percent have computers with control function capacity.
Nuclear power generation	Light-water reactors currently dominate the industry and one high-temperature gas reactor is in use. Some development work has been done on breeder reactors. Efforts are underway to standardize nuclear power plant design in order to facilitate the increasingly complex licensing procedures.	Greater demand for scientific and technical specialists and security personnel than conventional power plants. Higher skill requirements for control room operators and construction and maintenance crews.	By the end of 1977, 49 licensed nuclear plant were in operation, providing about 9 percent of total generating capacity.
Exhaust gas scrubbers for solid coalburning plants	Exhaust gas scrubbers remove sulfur dioxide by forcing exhaust gases through a water and limestone slurry or some other chemical process prior to venting the gases into the atmosphere. Scrubbers still have a number of problems that must be solved before they can be considered completely successful.	Increased labor requirements for construction, operating, and maintenance activities.	More than 24 scrubbers were installed or under construction in 1974, according to Federal Power Commission data. The number of installations is expected to increase.
Extra-high-voltage (EHV) transmission of electric power	EHV technology has made possible the economical transmission of large blocks of power, facilitating the development of regional power pools.	Some increase in difficulty of work due to use of higher towers and need to use heavier equipment on higher voltage lines. Use of "barehand" maintenance techniques speeds repairs but requires special training.	EHV technology now dominates the transmission of electric power.
Mechanized vehicles for construction and maintenance of power lines	Productivity has been increased in the construction and maintenance of transmission and distribution lines by the combination of small, highly trained line crews with a large number of especially developed work vehicles.	Line crews now handle a greater amount of work than was previously possible; consequently the number of people in this occupation has not grown as rapidly as the size of the transmission and distribution network. Demand has increased for vehicle maintenance personnel.	Presently in wide use.

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1972, lead time was about 7 years;[4] by mid–1977, lead time had increased to roughly 10–12 years.[5] Most nuclear plants are virtually custom built, which is time consuming and expensive. Standardized plant designs (perhaps based on previously approved designs) that can be mass produced and approved as a group could shorten lead times by several years. The Nuclear Regulatory Commission is encouraging such an approach, and standardized plants are beginning to be constructed. To hasten the process of approving sites for nuclear power plants, the Federal Government is proposing that States create, in effect, "site banks" by approving areas for nuclear plant construction in advance of any licensing requests by utility companies.[6]

There are several types of nuclear reactors in commercial operation or under development. Light-water reactors (LWR's) presently dominate the nuclear power industry. These reactors use enriched uranium-235 for fuel, which is somewhat limited in supply, and they utilize heat energy from the reactor core to convert water into the steam that drives the turbine-generator units. Light-water reactors with over 1,000-Mw capacities are now in operation.

High temperature gas reactor (HTGR) technology is well developed in Europe. Only one gas-cooled reactor, of 330 Mw, is operating in the United States. Gas-cooled reactors offer greater thermal efficiency than light-water reactors (39-percent efficiency for HTGR's, compared to the 33- to 34-percent efficiency of LWR's), reduce the effect of thermal pollution, and use thorium as well as enriched uranium for fuel. For gas-cooled reactors to be commercially successful, their total generating costs must be competitive with those of light-water reactors and coal-fired plants, and conclusive cost data are not yet available.

A third type of reactor—the breeder reactor—is in the development stage. The breeder reactor converts uranium-238 or thorium-232 to fissionable plutonium-239 or uranium-233 at a faster rate than it consumes fuel, in effect creating more fuel than it uses. Most of the development work has been concentrated on the liquid-metal fast-breeder reactor, as this type of reactor has the fastest conversion rate. The future of breeder reactor technology is uncertain, however, since development work is expensive and technically difficult and requires extensive use of plutonium.

Labor requirements in nuclear plants differ from those in fossil-fuel plants of similar capacity. Nuclear plants tend to have more highly trained staffs, including a larger number of scientists, engineers, and technicians. More security personnel are required at nuclear plants—a service which used to be contracted out to private guard and detective agencies but is now being handled to a larger extent by the utility firms themselves. Nuclear plant operators must be trained to work with fissionable material and must be licensed by the Federal Government. Construction and maintenance work in nuclear plants is done to very exacting specifications and requires craft workers with very high levels of skill. Maintenance crews may be slightly larger at nuclear plants because maintenance procedures are more complex. Regulations concerning radiation exposure sometimes necessitate the use of protective clothing, which might hamper working ability and decrease efficiency to some extent.

Coal for fuel

Coal is the most abundant energy source in the United States and was the primary fuel for steam generating plants before 1965. Between 1965 and 1972, many utility firms switched from coal to oil. Initially, this switch occurred because oil was less expensive, but during the latter part of this period pollution control also became an important consideration. Much of the coal available in the United States has a high sulfur content and is a major source of air pollution from generating plants. Oil is a cleaner burning fuel. By 1974, the problems inherent in heavy reliance upon oil became clear: limited domestic supplies and dependence upon foreign sources. Coal, therefore, has become important again to electric utilities.

The sulfur dioxide emissions that result from burning solid coal remain a major air pollution problem. There are several possible solutions. There is low-sulfur coal available, primarily in the western part of the United States. This coal generally has a lower Btu (British thermal unit) content than high-sulfur coal, requiring a greater quantity to be burned for the same energy input. The differences in quantity used would have an impact on generating plant storage capacity and on fuel and ash handling. There are also transportation expenses involved when using western low-sulfur coal in the eastern part of the country.

A somewhat controversial solution is the installation in generating plants of exhaust gas scrubbers, which are cleaning devices that remove much of the sulfur dioxide from exhaust gases. Scrubber technology is still developing and needs further refinement to be fully effective. Scrubbers are expensive—they can add up to 50 percent of the cost of a boiler-generator system. They also consume from 1.5 to 5 per-

[4] "Nuclear Survey: Lead Times Stabilizing," *Electrical World*, Oct. 15, 1972, p. 7.

[5] "Carter Seeking Speed-Up of Nuclear Plant Licensing," *The Washington Post*, Aug. 4, 1977, p. A4.

[6] Ibid.

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cent of the plant's output.[7] Reliability has also been a problem. The solution so far has been to build in redundant equipment or to step up maintenance operations—both of which are expensive procedures. In one of the earliest scrubber installations, the plant maintenance force had to be increased by 50 percent to handle equipment breakdowns and corrosion problems.[8] Many scrubbers produce large amounts of watery sludge as a waste product. The disposal of this sludge is a major unresolved problem.

The number of scrubber installations will probably increase because, in spite of the problems and expenses involved, scrubbers do provide control over some of the pollutants caused by generating plants. Scrubbers are complex equipment, and, as the number of installations increases nationwide, the number of maintenance workers needed in the industry also will rise.

An alternative to the direct burning of coal is the conversion of coal to a gas or a liquid. For electric utilities, advantages include the capability to remove sulfur and ash during the conversion, thereby reducing air pollution when the converted coal is burned. The coal converted by at least some of the several gasification and liquefaction procedures that have been proposed can be transported by pipeline. At present, however, coal gasification and liquefaction on a large scale are not commercially available, and the cost and reliability of the processes have yet to be proven. Given the present technology, these alternatives are more expensive than the installation of exhaust gas scrubbers in generating plants.[9]

Some generating plants that were designed to burn oil or natural gas can also burn coal in liquid or gaseous form. Converting these plants to burn solid coal, however, would be prohibitively expensive and, in some cases, where insufficient land is available for coal storage and for coal and ash handling equipment, technically impractical.

Labor requirements in coal-fired plants tend to be higher than those in oil- or gas-fired plants. Using coal requires moving it from storage areas near the plant to furnaces in the plant and cleaning out the ash residue after the coal is burned. This work is performed by "fuel and ash handlers," a semiskilled occupation. The future use of coal in liquid or gaseous form, if ultimately proven commercially attractive for U.S. utilities, would eliminate the need for this occupation (as has occurred in gas-fired plants) and reduce total utility industry labor requirements. Research on conversion of coal into synthetic gas or to liquid form has been intensified because of vast coal resources available within the United States and concern over future availability of oil and natural gas.

High-voltage transmission

Extra-high-voltage (EHV) technology now dominates the transmission of electric power. Developments that have facilitated the growth of EHV transmission include the introduction of bundles of two or more conductors, insulator strings set in "V" configurations to control swing, the use in some instances of guyed structures in place of self-supporting towers, the use of aluminum and special steels in line structures for reduced maintenance requirements, and the use of helicopters to facilitate construction. As of August 1977, there were almost 117,000 miles of EHV transmission lines in service.[10] The development of EHV technology makes possible the economical transmission of large amounts of electric power over long distances, with significant reductions in right-of-way requirements and corresponding reductions in right-of-way maintenance operations compared to what would have been required using lower voltage lines. EHV interconnections presently cover most of the country.

The higher voltages involved in EHV transmission have caused some changes in work techniques. Line crews work on higher towers using longer, heavier "hot sticks" and the more modern "barehand" technique. "Barehanding" is a process in which the worker handling an energized circuit becomes a part of the circuit, with precautions against grounding (such as working in an insulated fiberglass bucket or on a fiberglass ladder suspended from the line tower). Under the proper circumstances, barehand repairs can be completed in a fraction of the time required by more traditional methods.

Power line construction and maintenance

Construction and maintenance techniques continue to improve, with crew size and productivity undergoing change. The use of helicopters in rough terrain, chemicals to control brush on rights-of-way, and lighter metals in structures are among changes that have reduced construction time and maintenance requirements for line crews.

The vehicles used in constructing and maintaining transmission and distribution (T&D) lines have un-

[7] Paul H. Weaver, "Behind the Great Scrubber Fracas," *Fortune*, Feb. 1975, p. 112.

[8] Ibid.

[9] Lawrence H. Weiss, "Clean Fuel and Scrubbing Compared," *Electrical World*, Oct. 1, 1976, pp. 70–73.

[10] Department of Energy, Federal Energy Regulatory Commission.

[11] "Mechanization Revolutionizes Construction," *Electrical World*, June 1, 1974, p. 164.

[12] Ibid.

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dergone considerable technological change over the past 10-15 years—a change that has had quite an impact on T&D workers. These vehicles (mostly truck chassis weighing 22,000 to 40,000 lbs.) carry hydraulically operated equipment, such as 360-degree rotating derricks and pole hole diggers, or aerial lifts with booms that can range from 20 to 150 feet high, or plows, backhoes, earth augers, cable pullers, etc. This mechanization of mobile equipment was well underway by the early 1960's and has continued to grow rapidly, as illustrated by the increased use of aerial lifts: The average utility used 10 aerial lifts in 1962 and 97 lifts in 1974.[11]

Vehicle mechanization grew so rapidly because utilities needed to keep up with increasing construction demands with minimum increases in cost and in the size of construction work crews. Additionally, the cost of labor was increasing more rapidly than the cost of construction equipment. In the mid-1960's, for example, the price of a 1/2-ton pickup truck was equal to a top line crew worker's pay for 455 hours of work. In 1974, the cost of a new pickup truck was equivalent to a top line crew worker's pay for only 325 hours.[12]

Mechanized mobile equipment has made possible a reduction in the size of construction work crews and T&D line crews. Large, all-purpose line trucks are used where work is concentrated in one area—but generally with crews of 6 people rather than the traditional 8- to 9-person line crews. A fleet of smaller special-purpose vehicles with 2 or 3 crew members each, equipped with 2-way radios and backed by computerized scheduling of work assignments, can generally provide the greatest productivity for work scattered over large areas. A modern transmission line crew might typically consist of 4 aerial lifts, an earth auger, and a digger/derrick truck with 2 crew members each, and a pickup truck for the supervisor—7 specialized vehicles and a crew of 13 highly skilled workers.

The growing mobile fleet requires an increasing commitment of resources—labor, equipment, and managerial skill—for maintenance and repair operations. Over 90 percent of the utilities that own their vehicle fleets operate service and repair facilities (although some major repair work may be contracted out).[13] Scheduled maintenance programs are necessary to maximize vehicle availability and minimize fleet operating costs. Managerial ability, sometimes combined with computerized scheduling and record-keeping, is necessary to operate such programs. Maintenance personnel need to be familiar with both automotive and hydraulic servicing and repair.

[13] Michael G. McGraw, "Fleet Management Becomes More Sophisticated," *Electrical World*, Aug. 1, 1975, p. 38.

Investment

Capital expenditures

Expenditures for new plant and equipment in the major industry group electric, gas, and sanitary services (SIC 49)[14] rose from $5.2 billion in 1960 to $25.8 billion in 1977, an average annual increase of 11.6 percent. (In real terms, however, the increase is not as great since the price of plant and equipment has risen over this period.) Most of the growth occurred after 1967, with expenditures increasing at an average rate of 10.8 percent a year between 1967 and 1977. The average rate of growth between 1960 and 1967 was 7.8 percent a year.

Capital expenditures per nonsupervisory worker in the industry have grown almost fivefold over the past 17 years, from $10,143 per worker in 1960 to $46,638 per worker in 1977—an average increase of 10.8 percent a year. The average annual growth rate was 7.9 percent during 1960–67 and 10.0 percent during 1967–77.

Electric utilities account for the largest portion of the industry's capital expenditures, with 69.1 percent of 1960 expenditures and 83.7 percent of 1977 expenditures. Electric utilities spent $3.6 billion in 1960 and $21.6 billion in 1977—an increase averaging 13.2 percent a year. The average annual growth in spending during 1960–67 was 8.9 percent; the rate during 1967–77 was 12.1 percent.

The industry went through a period of economic uncertainty during the mid-1970's which had an impact upon its capital spending activities. This is a highly capital-intensive industry which for more than 15 years had a steady, predictable growth in demand averaging 7.4 percent a year[15] —a situation that allowed an orderly growth in capital expenditures. However, in 1974 and to a lesser extent in 1975, construction and fuel costs rose rapidly while the growth in demand was well below the historical rate. High interest rates and low stock market prices limited the ability of utilities to raise funds in the money market. Problems with regulatory and environmental concerns continued. In response to this situation, electric utility firms cancelled or postponed a considerable part of their planned capital expenditures. According to *Business Week*, 170,000 Mw or

[14] Data are available from the Department of Commerce only for this broader SIC 49 industry grouping, which, in addition to including establishments which generate, transmit and/or distribute electricity, gas, or steam (SIC 491, 492, and 493), also includes establishments which distribute water, provide sanitary services, supply steam, and operate water supply systems for irrigation.

[15] Carol J. Loomis, "For the Utilities It's a Fight for Survival," *Fortune*, Mar. 1975, p. 97.

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47.2 percent of a planned 360,000-Mw generating capacity were cancelled or significantly delayed in 1974.[16] *Electrical World* noted that in 1975 capital spending declined for the first time in the industry's history.[17]

Expenditures turned upward again in 1976 and 1977. This resumption of capital spending reflected the general improvement in economic conditions after 1975, the inability of utility companies to further postpone to a significant degree generating plant construction in the face of growing demand, and concern over power shortages and service reliability.

The outlook over the next several years is for a continued increase in expenditures. McGraw-Hill's 1977 annual survey of business plans for capital spending[18] indicated that the electric utility industry planned to spend $25.2 billion for new plant and equipment in 1978, $27.5 billion in 1979, and $29.2 billion in 1980. Approximately 87–88 percent of these funds were to be for machinery and equipment; the balance was for buildings and vehicles.

A slower rate of growth in demand could ease the pressure on generating capacity. Demand (kilowatt-hour sales) actually dropped slightly in 1974—a short-run response to conservation efforts, the economic downturn, and unexpectedly large increases in the price of all energy sources, including electric power. After a period of adjustment to higher energy costs, demand began to grow again, but at less than the historical rate of 7.4 percent a year. The Federal Energy Regulatory Commission's Bureau of Power considers a growth rate of 5.7 percent a year to be likely between 1977 and 1986.

Funds for research and development

There are several sources of research and development funds in the electric power industry: Equipment manufacturers, the Federal Government, and the utility companies themselves. Equipment manufacturers perform much of the basic research and development (R&D) work applicable to the electric power industry, recouping their costs by selling the equipment they develop to the power companies. Federal R&D funds have been largely concentrated in the development of nuclear power.

According to the Federal Energy Regulatory Commission, annual R&D expenditures for class A and class B electric utilities[19] were in the range of $37 million to $47 million between 1966 and 1970, rising to $239 million in 1973. Expenditures declined slightly to $234 million in 1974, but rose again to $290 million in 1976. Only about 20 percent of these funds were spent directly by utility companies. The majority of the funds went to organizations such as the Edison Electric Institute, the Electric Power Research Institute, and the Battelle Memorial Institute.

Production and Productivity Outlook

Output

Output per employee hour increased at an average annual rate of 4.6 percent from 1960 to 1977. The growth rate was higher during the 1960-67 period (6.3 percent per year) than between 1967 and 1977 (3.0 percent per year).

Output has grown steadily for many years. In 1974, however, demand for electricity declined in response to price increases, economic conditions, and conservation efforts. This contributed significantly to the first drop in this industry's output since at least 1947. In 1975, output returned roughly to the 1973 level, and increased again in 1976 and 1977.

Output will probably continue to increase through the coming decade for the industry as a whole. Demand for electricity, as discussed earlier, is expected to increase steadily. For gas utilities, however, the outlook is not so positive. The supply of domestic natural gas is declining and synthetic gas is not expected to be available in significant quantity until the late 1980's. Use of imported natural gas can be increased to some extent. The net result is a projected slight decline in the gas supply through 1985.[20]

Productivity

Output in electric power and gas (BLS weighted index) increased at an averaged annual rate of 5.9 percent between 1960 and 1977. During the 1960-67 period, growth in output averaged 6.9 percent a year, while the 1967-77 period experienced a lower average annual growth rate of 4.2 percent.

There may be a long-term decline occurring in the rate of productivity growth. Although output continues to rise at a faster rate than employee hours, the rate at which output is growing peaked in 1970 and declined through 1977, while the rate of change for

[16] "Utilities: Weak Point in the Energy Future," *Business Week*, Jan. 20, 1975, p. 46.

[17] "27th Annual Electrical Industry Forecast," *Electrical World*, Sept. 15, 1976, p. 58.

[18] *Business Plans for New Plants and Equipment, 1977–80*, 30th Annual McGraw-Hill Survey (New York, McGraw-Hill Publications Co., Economics Department) May 6, 1977.

[19] Class A and class B electric utilities have accounted for roughly 80 percent of total kilowatt-hour sales over the past decade.

[20] *United States Energy Through the Year 2000 (Revised)* (U.S. Department of the Interior, Bureau of Mines, Dec. 1975), p. 65.

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employee hours continued to grow steadily through 1974 and was only slightly lower in 1975, 1976, and 1977. Hence, output per employee hour is growing, but the average annual rate of growth has been gradually declining since reaching a peak in 1964. The productivity growth rate for nonsupervisory workers has been higher, and the increase in employment has been lower, than for all employees.

Electrical World publishes a continuing survey of generating costs for electric utility steam plants that includes data on the number of operating and maintenance employees per Mw of net output. In 1960, 0.306 employees were required per Mw of net output.[21] By 1976, however, labor requirements had declined by 60 percent to 0.122 employees per Mw.[22] The survey indicates that labor requirements tend to be lower for larger generating plants. The survey also indicates that labor requirements vary by type of generating plant. Nuclear plants have the greatest labor requirements per Mw, needing more people in all occupations (except fuel and ash handlers) than the other types of generating plants. Coal-fired plants have the second highest level of labor requirements, oil-fired plants the next, and gas-fired plants the lowest.

The size of generating units is not likely to increase as rapidly in the future as over the past 20 years, and nuclear and coal-fired plants are expected to be the main sources of electric power in the future. Labor requirements per Mw, therefore, may not continue to decline as much as they have over the past decade.

Employment and Occupational Trends

Employment

Employment in electric power and gas, according to BLS data (SIC 491, 492, 493), increased rather slowly from 582,300 in 1960 to a peak of 684,200 in 1974 and then declined to 673,000 in 1977. The average annual growth rate over the 1960–77 period was 1.2 percent, with most of the growth occurring after 1967. The average annual rates of change for 1960–67 and 1967–77 were 0.4 percent and 1.3 percent, respectively. BLS projections to 1985 indicate that growth in employment may average 0.7 percent a year between 1977 and 1985.

Employment growth for nonsupervisory employees has been slower than for all employees; nonsupervisory workers increased at an average rate of 0.8 percent a year between 1960 and 1977. The number of nonsupervisory workers was about the same in 1960 and 1967 but then grew between 1967 and 1977 at an average annual rate of 0.8 percent.

Occupations

Technological and other factors are altering to some extent the occupational structure in the electric power and gas industry. One area of change is in the balance of supervisory and nonsupervisory workers: Nonsupervisory workers have declined from 89 percent of total employment in 1960 to 83 percent in 1976.

A comparison was made of labor costs for various occupations between a group of large generating plants (averaging 2,626 Mw) and a group of smaller plants (340 Mw) in 1975.[23] Labor costs per net Mw for the smaller plants were approximately 35 percent higher for supervisors, 315 percent higher for operating personnel, 48 percent higher for maintenance personnel, 200 percent higher for fuel and ash handlers, and 188 percent higher for clerks.

The types of fuel used by generating plants also affect occupational requirements. Fuel and ash handlers are not required for plants using natural gas but are needed in plants that burn coal and, to some extent, in plants that burn oil. Also, nuclear plants require more specialists than any type of fossil-fuel plant. As nuclear plants and coal-fired plants are expected to become the dominant types of power plants over the next decade, the occupations of specialist and fuel and ash handler should become more important.

Employment is projected to increase in six of the eight major occupational groups, with the largest increases expected to occur among professional and technical workers, managers and administrators, and craft workers. Specific occupations in which increases are expected include electrical engineers, electronic technicians, computer specialists, computer peripheral equipment operators, construction electricians, plumbers and pipefitters, boiler-truckdrivers. Some of the occupations for which declining employment is projected are keypunch operators, furnace tenders and stokers, cleaning service workers, and construction laborers (except carpenters).

[21] Leonard M. Olmsted, "14th Steam Station Cost Survey," *Electrical World*, Oct. 18, 1965, p. 104.

[22] Friedlander, "20th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1977, p. 44.

[23] Results from the survey of steam generating plants by *Electrical World* indicate that the cost of operating and maintenance employees per Mw of net output declined steadily from 1960 to 1970, then rose somewhat in 1972, and declined again in 1974 (although not returning to the 1970 level). In this study, 1960 data are from the 14th Steam Station Cost Survey, *Electrical World*. Data for 1962–72 are from Leonard M. Olmsted, "19th Steam Station Cost Survey," *Electrical World*, Nov. 15, 1975, p. 44. The 20th Cost Survey, in 1977, did not have such detailed information for labor cost.

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Some decline in the number of power plant operators is anticipated. Larger and more efficient equipment is expected to create increases in output with little or no increase in labor requirements. The same number of people, for instance, can operate a large generator or a small one.

The occupational structure at a fossil-fuel generating plant visited by BLS staff tends to support this projection. This plant utilizes three generating units: Two small units (175 Mw each) operated from one centralized control room and one large unit (850 Mw) that has its own control room. Both control rooms are run by four-person operating crews, although the skill requirements are higher for the larger generating unit.

However, a nuclear generating plant also visited by BLS staff has somewhat different occupational requirements. This plant uses larger and more highly skilled control room operating crews—seven to eight people, including a minimum of five operators licensed to work with fissionable fuel. Additionally, there is an ongoing training/retraining program at the plant to which operators are assigned on a rotating basis. If this plant is representative of nuclear plants in general, then an increase in the number of nuclear plants could reduce the projected decline in the number of power plant operators.

There has been some concern in the electric power industry about possible shortages of skilled construction and operating personnel during the coming decade. Such shortages would have greater impact upon nuclear generating plants because of the many special skills involved. Among the occupations critical for constructing and operating nuclear plants, where shortages are possible, are nuclear, mechanical, and electrical engineers, reactor operators, health physics/radiation monitor technicians, millwrights, and nuclear-qualified welders (most of whom come from the ranks of steam/pipe fitters and boilermakers). [24]

A new labor demand model that forecasts power plant construction employment has been developed by the Departments of Labor and Energy and the Tennessee Valley Authority. [25] The model covers 1978–81 and breaks employment estimates down by region, occupation, and type of generating plant. This model could be a useful tool for utility companies in estimating their employment needs.

Some increase is expected in occupations concerned with the transmission and distribution of electric power. The number of line and cable workers should increase. Increased use of automatic equipment in substations—allowing more remote control operations—may cause a decline in regular substation operators but an increase in the more highly skilled mobile substation operators, who travel from one remote-controlled substation to another.

Adjustment of workers to technological change

Training programs are being established to facilitate adjustment of employees to the requirements of new technology. Control room operators in nuclear generating plants, for example, are licensed by the Nuclear Regulatory Commission (NRC) to manipulate the controls of a nuclear reactor. The training program used in the plant visited by BLS staff to prepare operators for the NRC licensing test requires between 6 months and a year to complete and includes extensive training in nuclear physics, radiation protection, and power plant operations. The NRC operator's license must be renewed every 2 years; since nuclear power generation is a rapidly evolving technology, the power company maintains an ongoing retraining program for its operators. Some utilities are installing simulators that will be used to train nuclear operators. Control room supervisors are required to hold a senior operator's license which, in the company visited, requires an additional 6 months of training.

About one-half of the workers in electric and gas utilities are unionized. Of the several unions representing utility industry employees, the largest are the International Brotherhood of Electrical Workers and the Utility Workers Union of America.

Specific provisions relating to technological change are not commonly found in collective bargaining contracts for this industry. There are, however, contract provisions pertaining to seniority, layoffs, job training, and promotions that could be applied to job losses resulting from technological change.

[24] *Project Independence* (Federal Energy Administration, Nov. 1974), pp. 61–72.

[25] Willis J. Nordlund and John Mumford, "Estimating Employment Potential in U.S. Energy Industry", *Monthly Labor Review*, May 1978, pp. 10–13.

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Technology and Labor in Insurance

Gustav A. Sallas

Summary

Insurance carriers (SIC 63) were the first industry to apply computers to business office procedures on a wide scale with the advent of electronic data processing (EDP) in the early 1950's.[1] Since then, the industry's substantial accounting and statistical requirements, its vast data storage and retrieval operations, and the mass of paperwork it produces have pushed it to the forefront of EDP utilization. Practically every function of an insurance carrier has been computerized, and almost all firms have applied EDP and related technology to at least part of their operations. By 1985, the industry may employ more than 30,000 persons in computer positions.[2]

The spread of EDP and the growth of the industry have been mutually supporting. A rising population in a growing economy, with concomitant increases in personal income and expenditures for insurance, have made it nearly impossible for firms to function without EDP. Moreover, computers have made it easier for carriers to take advantage of statutes allowing the underwriting of different lines of insurance by the same company. The main problems created by this rapid growth have been gigantic and cumbersome files, interminable transcription of the same data from one form to another, and a myriad of tedious and repetitive operations; for all of these, EDP and related technology is ideally suited.

New technology has brought about substantial improvements in productivity in a wide range of labor-intensive insurance processing operations. The more widespread use of computers, along with optical character recognition equipment, remote computer terminals, microfilm technology, and related innovations, has reduced unit labor requirements in data storage and retrieval, computations, billing functions, and processing of claims, bids, and proposals.

Employment in the insurance industry increased at an annual rate of 2.0 percent during 1960–78 as personal consumption expenditures for insurance reached higher levels. A total of 1.2 million persons were employed in the industry in 1978. The number of persons working in clerical occupations is expected to rise at a slower rate than total employment during the period 1978–85 as computers and related technologies increasingly reduce labor requirements in data processing tasks.

Technology in the 1980's

Technological developments in the insurance industry have centered on the application of EDP to an increasing number of the industry's functions, particularly to the management of information. A summary of the major technological changes is presented in table 4.

To cope with the huge volume of paperwork, calculations, and records generated by rapid industry growth, an increasing number of firms are using EDP. Computer programs have been developed for a wide range of insurance industry functions, ranging from actuarial research to claims processing. In addition, EDP is used extensively by the industry to perform basic office tasks such as word processing (typing, copying, printing), mail handling, and check writing.

Technological advances in the industry have led to the merger of a vast electronic data base and computation capability with on-line communications networks, output devices, and office operations equipment. Utilizing this technology, many of the major operating functions for all insurance lines may be performed by a central computer on demand from a terminal in the home office or in any field office (including overseas offices), with the results made available either through visual display devices or on hard copy. More complex operations are constantly being devised, and worldwide electronic communications and operations networks are being created. In addition to EDP, more extensive use of equipment such as closed-circuit TV and other audiovisual equipment for training, new and improved copying devices, text-management equipment, and electronic calculators also have improved efficiency in insurance industry operations.

[1]Standard Industrial Classification 63 comprises stock and mutual enterprises which underwrite all types of insurance, primarily life, accident and health, property, casualty, surety (financial responsibility), and title insurance. This study does not include independent agents and brokers (SIC 64) who sell insurance underwritten by others or who render services to insurance carriers or policyholders.

[2]Unpublished BLS data which include both insurance carriers (SIC 63) and insurance agents and brokers (SIC 64).

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Table 4. Major technological changes in the insurance industry

Technology	Description	Labor implications	Diffusion
Electronic data processing (EDP)	EDP is being applied to an increasing number of insurance industry functions including billing and collection, actuarial research, underwriting, and claims processing. Minicomputers are being introduced more widely in various departments within an insurance firm and in some instances are being joined with a central computer. These small computers edit, correct, and preprocess data at the department level before the data are transmitted to the main computer installation. They also retrieve and manipulate data already stored in integrated electronic data base/data communications systems and carry out other functions.	EDP technology has reduced unit labor requirements for file clerks, typists, and other clerical staff. Employment of programmers, computer operators, and related staff has increased along with the number of installations.	EDP technology will be diffused more widely over the next decade as new, less costly, and technologically improved small computers become available.
Integrated electronic data base/ data communication systems	All data are recorded on magnetic tape, discs, or drums and processed through a central computer installation. Information can be retrieved instantly at base or remote locations anywhere in the country and displayed on video screens or in printed form. The data may be updated, deleted, or segmented for specific functions. The central processing unit can activate various electronic devices which will utilize the stored data to perform functions such as accounting, billing, internal and statutory reports and statistical tables, correspondence, and promotional brochures.	Reduces the number of file clerks required.	The number of systems in use is increasing. Most of the major carriers have already accomplished the conversion to the system; others are using the building block approach, computerizing their files and operations systems function by function, with a view to eventual integration.
Data input devices:			
Optical character recognition	Photoelectric devices are being used to scan encoded documents, interpret them, and produce a magnetic tape which triggers operating systems and also constitutes a permanent record of each transaction. They can produce output as disks or video display devices.	Reduces the number of keypunchers and mechanical systems required for EDP.	Widespread, particularly in premium billing and collection operations, promotional campaigns, and data bank input.
Mark sense input system	Special writing tools which trace symbols (lines, dots, or curves) on ordinary paper are being used to produce information readable by computers.	Reduces the number of keypunchers required for EDP.	Not widely used as yet. Expected to gain acceptance in the near future.
Portable computer terminal	Microcomputers in briefcases, complete with keyboard, video display unit and line printer, are being joined to integrated electronic data base/data communications systems by ordinary telephone.	As yet minimal.	Expected to be used more extensively by salespersons.

Planning and implementing EDP applications are preceded by intensive analysis of existing procedures and practices in order to develop the appropriate program, and conversion to EDP (including personnel retraining) is accomplished gradually to avoid disrupting current operations. With the advent of the new generation of small computers and the corollary drop in computer system operating costs, EDP and integrated systems will be widely applied in the industry during the 1980's.

EDP applications

The number of insurance industry functions which are being converted from manual to EDP operation is growing. Computers are being applied to a wide range of major activities including billing and collection, actuarial research, underwriting, and claims. The industry consensus is that during the balance of the decade and through the 1980's computer technology will be extended to other areas, with unit labor requirements in clerical operations expected to continue to decline. Employment of computer programmers, systems analysts, and other computer specialists is expected to continue to increase as computer use grows.

The further introduction of minicomputers is expected to bring about additional changes in insurance industry operations. Until recently, the insurance industry installed increasingly larger and more complex EDP hardware. This compelled the user to attempt to process through a large computer a growing number of minor operations (as for example, the management of office supplies). The minicomputer will be used more extensively to perform such tasks as payment of policy dividends and claims and, through a terminal, to edit and process data prior to input into the central system. A minicomputer programmed for an increasing number of insurance applications ultimately may replace the desktop calculator in an insurance firm's head office and branches.[3]

Billing and collection. A common EDP application is premium billing and collection. Although some carriers prefer to collect premiums through their agencies, the trend is toward home office collection, often through the "turnaround" billing system.

In turnaround billing, a machine readable notice of premium due produced by the computer is returned by

[3]At present, branch offices have little or no processing equipment and often no EDP systems whatever. Most branch equipment consists of key-entry devices for input to home office computers. This is particularly the case among property and liability insurance carriers. Current technology permits the home office to transmit computer programs from the central EDP installation, thereby eliminating the need for programmers in field offices.

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the policyholder with the remittance. The computer puts the payment data on a magnetic tape or disk for the accounting department, calculates the agent's commission on each premium, and credits the appropriate account. These systems are currently operating at the rate of about 5,000 remittances an hour, but equipment already available is capable of handling over 40,000 remittances an hour.

Actuarial research. Computers also are reducing unit labor requirements in actuarial tasks. In life insurance, actuarial research yields studies and projections based on mortality and morbidity (the proportion of disease cases to population) rates as well as on records of premium earnings and of policy lapses and maturity. An actuarial department calculates each carrier's premium and dividend rates and provides risk selection guidelines, among other things. Actuarial work is well suited for EDP since it requires the quick retrieval of large amounts of statistical data, the performance of sophisticated mathematical analyses and complex computations, and the production of statistical tables to meet the company's reporting requirements.

Underwriting. Underwriters review all policy applications, pass upon endorsements (changes to policy conditions), and determine the amount and type of reinsurance required. Although the decision to accept or reject each risk must still be made by a trained underwriter, EDP experts and underwriters are working together to expand the computer's participation in underwriting. Operations already performed electronically include logging for transaction control, file search for possible related material, and coding, rating, and policy issuance.[4] Electronic processing can control and monitor a policy application through the entire underwriting and policy issuance cycle, producing daily reports on case status at each work station, thereby saving time and labor—an important factor since 10,000 new and renewal applications may be processed daily in the underwriting department of a major carrier. One property and liability company, for example, reduced the personnel in its policy-issuing operation alone by one-third after conversion to EDP.[5]

Claims. The application of EDP to claims processing varies widely with the type of insurance involved; even within the same line, the time frame over which a claim must be serviced greatly affects the automated processes involved. The widest variation in claims procedures occurs within the life and health insurance companies. Claims that call only for death benefit payments require only eligibility verification and check issuance. In integrated electronic systems, the search capability of the system identifies all policies for a given claimant, and the data base will show the current status of the policies, compute the amounts payable, activate the check-issuing devices, make the appropriate entries into the general ledger, and block any other transaction from occurring.

Health and disability insurance claims involve more intricate processes which require complex EDP programs. These policies provide for payments for services as well as income protection and indemnity. Health and disability claims require large numbers of examiners, file clerks, and typists. In an EDP system, the examiner can view the claim history file on a video screen, determine coverage, adjudicate the claim, calculate the benefits, issue payment checks, and generate the required correspondence.

In the property and liability field, the growing complexity of the coverage has placed a strain on claims processing and encouraged more extensive application of EDP. For example, no-fault automobile insurance in many cases sets a time limit for the insurer to respond to the claim. To achieve growth with a stable work force will require improvements attainable only through electronic automation—a significant challenge in light of the substantial manual processing of claims that occurs in many property and liability companies. The potential of EDP to improve efficiency in claim processing is illustrated by the following example of a system in operation. An appraiser involved in an auto damage claim first checks eligibility and coverage through the home office computer, assesses the damage, and then writes a check to settle the claim. A form filled out at settlement is fed into a transceiver which sends an image by telephone line to the home office (usually at night) for accounting and central files. At the receiving end, the unattended device produces a photograph of the forms and turns itself off when the transmission is completed.

Integrated communication systems

Electronic data base/data communication systems are being applied to the substantial data handling requirements associated with the insurance industry. These data generally must be maintained in current form for several decades and are periodically required for immediate use at various locations in the home office and in the field. As many as 12 separate records are maintained on a given policy, spread among various departments and often duplicated in field offices. In most instances, these functional files include duplicate information. The data overlap often results in one file being current while its duplicates remain static and become outdated.

Integrated electronic data base/data communication systems have several advantages, including the capability

[4]Insurance policies usually consist of three parts: (1) A jacket, or printed section, which contains only constants applicable to a given carrier or kind of policy; (2) the declarations—a printed form bearing a typed description of the variables involved, such as premium or particular risks; and (3) endorsements, which usually are extensions of either the jacket or the declarations. (Both the printing and typing of policies have been computerized.) Surveys in the property and liability lines have shown that electronic processing of the declarations eliminates an error factor of approximately 8 percent which plagues the manual operation.

[5]*LOMA Resource*, Life Office Management Association, March/April, 1976.

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to consolidate all data related to a single policy in the company's central computer installation. The systems search capability permits instant identification of all policies connected with one name and of all names connected with one policy; review of all documents which meet a given specification; and browsing through entire files by flashing their contents on a video screen document by document. In advanced installations, the information is stored on magnetic tape or in disk packs which can hold up to about 30,000 pages of data. The files may be updated or deleted at will, and may easily be segmented for specific purposes and the various segments protected from unauthorized use. To protect the data from accidental destruction, duplicate disks or tapes are kept, usually off premises. Through advances in communication technology, data are accessible rapidly at all stations—immediate and remote—at terminals equipped with video display devices and line printers. Each system is linked by a communication and teleprocessing network of ordinary telephone circuits and leased telephone or telegraph lines. The integrated electronic data base/data communication system produces internal statistical statements on demand as well as the periodic reports required by regulatory agencies. Because of their capability to improve data handling, electronic data base/data communication systems will be used more extensively over the next decade.

Data input devices

Electronic devices which feed into a computer directly from documents are increasing accuracy and displacing keypunch operators. Optical character recognition technology is expected to assist the industry to cope with the massive increase in paperwork to accompany future growth. Without such devices it would already be impossible for the large carriers to handle expeditiously the huge number of inquiries, applications, remittances, and claims they receive every day.

Optical character recognition (OCR) is the instant interpretation and transmission of the symbols and alphanumeric characters which constitute a coded entry, by a photoelectric device known as an optical scanner. In the insurance industry, the optical scanner is used primarily for premium billing and collection. Additional uses are being developed in the processing of other documents which can be preprinted or encoded in machine readable form, such as policy applications, surrender notices, and reinstatement requests, as well as loan applications in life insurance and loss statements in property and casualty claims.

Coded machine readable documents can be produced by the computer or independently by special purpose typewriters and by the "Mark Sense" system, which involves the use of graphic input devices. These consist of a form listing a number of specific pieces of information, a writing tool for touching the items to be entered, and a photoelectric device which converts the data to digital form for the computer. Data from graphic input devices can be fed onto magnetic tape through a multiplex unit which can support up to 15 stations, each capable of carrying the data stream for a different insurance operation—such as underwriting, claims, or investments. These devices generally cut data entry time by 30 percent. In one instance, a carrier which processed about 400 bids and proposals a month with a staff of 11 was able to process nearly twice as many with a staff of 9 after switching from keypunch to an electronic pen.

Increasing utilization also is seen for the portable input-output device, or "briefcase terminal." The latest of these devices, which weighs under 15 pounds, is equipped with a keyboard, a microprocessor, a small video screen, and a compact line printer. Connected to an ordinary telephone (by placing the telephone receiver on a cradle in the device) and plugged into an electrical outlet, this device links an agent anywhere in the world with the company's central EDP installation. Hard copy is produced at the rate of 1,800 characters per minute. With instant access to the company's central computer 24 hours a day the year round, the agent can make a presentation and place the order for a policy.

Microfilm technology

Advances in microfilm technology are resulting in space savings in records storage, faster retrieval of policyholder information, and lower labor requirements for file clerks, typists, and other clerical staff. Microfilm processes are particularly advantageous to the insurance industry since large quantities of records are produced, such as policy and loan applications, paid drafts, and Medicare reports, that cannot be stored in the computer in digital form because of their format or statutory requirements.

The original microfilming process (which insurance companies pioneered in the 1940's) is giving way to microfiche, in which the roll film is replaced by 4″ × 6″ cards each holding about 100 frames (microphotographs) of legal size documents. (Already under development is a high-reduction technique known as ultrafiche, which will increase the capacity of the card substantially.) Microfiche expedites handling of hard copy documents and practically eliminates the storage space required for these items: The contents of about 140 file cabinet drawers can be stored in an 18-inch card tray. When microfiche is coupled with computer-output-micrographic (COM) devices, data are transferred directly from the computer to microfiche without need for intermediate hard copy. Multiple hard copies can be produced rapidly from the microfiche through a nonimpact printer.[6] Thus, the COM system can produce in a few seconds, from data in the computer, a microfiche frame for the record, available for instant viewing on a screen, and a number of hard copies for distribution. One life insurance carrier made two hard copies each of 230,000 documents from computer tape through microfiche in 15 hours—an operation that would

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have required 200 hours with an impact printer. Another carrier, which produced nearly 300 million microfiche frames in 1974, has plans to double this volume within the decade. The COM process is particularly advantageous for use in property and casualty underwriting where there are frequent changes in policy data (as when an automobile is traded in) many of which require transferring or reprogramming data needed for historical purposes.

Industry Outlook

The outlook is for continued expansion in the three major segments of the insurance industry—life, health, and property/liability. About two-thirds of the Nation's total population are covered by life insurance policies issued by the 1,750 life insurance companies with headquarters in the United States.[7] The face value of policies in force totaled $586 billion in 1960, $2,583 billion in 1977, and was projected by the U.S. Department of Commerce to reach $3,097 billion in 1979. The number of life insurance policies in force totaled 390 million in 1977, 38 percent more than in 1960. Purchase of new life insurance totaled $367.3 billion in 1977, compared to $74.4 billion in 1960, with the average amount of life insurance in force per insured family rising steadily and amounting to $36,900 in 1977.

Group life insurance, in particular, is gaining rapidly as life insurance benefits increasingly are being included in employee benefit programs, with coverage extended to dependents of group insurance certificate holders. Over 89 percent of all group life insurance contracts covered employer-employee groups in 1973 (most recent year for which data are available), and the average coverage per employee for these contracts was about $12,000. In addition, millions of employed and retired people are participants in retirement plans operated by life insurance companies. Even greater growth is anticipated in individual retirement plans under the Employee Retirement Income Security Act of 1974, which permits persons employed in firms with no private retirement plan to purchase an individual plan of their own.

Health insurance has expanded substantially. Expansion has been accelerated by the increasing inclusion of health benefits in labor contracts and by insurance company participation in the Medicare program enacted in 1966. At the end of 1976 (latest year for which data are available), 177 million persons were covered under provisions of one or more forms of private health insurance. Individuals under age 65 accounted for 93 percent of the total. The older groups were insured under private plans to supplement Medicare benefits. Premiums received by the industry for health insurance coverage rose to $24.3 billion in 1976, nearly double the premium income received in 1971.

The property and liability segment of the insurance industry also has recorded substantial growth. Between 1960 and 1977, net premiums written for property and liability insurance increased by almost 400 percent, from $15 billion to $74 billion. Auto insurance in 1977 accounted for about 42 percent of total property/liability premiums.

Accompanying the premium growth in the major categories of insurance, as discussed above, has been increasing diversification in the types of insurance underwritten by insurance carriers. Insurance companies also are merchandising mutual fund shares and other investment plans, and giant department store chains have formed insurance subsidiaries and are selling policies through in-store booths at their hundreds of outlets. Already many carriers have formed holding companies encompassing estate planning and equity investment, real estate, and data processing.

Employment and Occupational Trends

Employment

Insurance is a major industry that employed 1.2 million persons in 1978, or about 1 out of every 4 persons working in the finance, insurance, and real estate sector. Employment in insurance has been rising steadily as gains in personal consumption expenditures for insurance resulted in a steady rise in policies issued, premiums written, and insurance in force per insured family.

Total employment in insurance increased at an average annual rate of 2.0 percent during 1960-78. The annual employment growth rate was 1.8 percent during 1967-78 and 1.7 percent during the earlier 1960-67 period. Employment in the three largest components of the insurance industry—which combined accounted for about 94 percent of the total industry work force—fluctuated over the period 1967–78. Establishments primarily engaged in underwriting life insurance (SIC 631) continued to employ the largest number of employees, 522,500 in 1978, but their share of total employment declined from over 50 percent in 1967 to about 44 percent in 1978.

Second in size of work force is the fire, marine, and casualty insurance segment of the industry (SIC 633) which employed 460,600 people in 1978, a gain of 44 percent since 1966. Its share of total employment in the insurance industry rose slowly, reaching 39 percent in 1978.

[6]Several printing techniques are available which do not involve striking paper with a mechanical hammer, but use photographic, chemical, or magnetic ink processes and specially treated paper. In one of the most sophisticated of these, the Ink-jet Printer, a stream of magnetic ink droplets is shot towards the paper and deflected by electrostatic plates to form the desired character. Speeds in excess of 75,000 lines per minute are possible with the Ink-jet Printer, although such speeds are not yet available in commercial versions.

[7]The sources of statistics on amounts of insurance in force, number of policies in force, premiums written, number of persons covered, and related data included in this section for these three segments of the insurance industry are as follows: Life insurance, American Council of Life Insurance; health insurance, Health Insurance Institute; and property and liability insurance, Insurance Information Institute.

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The accident and health segment of the industry (SIC 632) is third in terms of employment, but it is the fastest growing and accounted for about 12 percent of the work force in 1978. Employment in establishments which underwrite accident and health insurance reached 138,900 persons in 1978, more than double their 1966 employment.

The rise in total employment in the industry has been accompanied by increased use of computer and related technology. Despite the fact that in many applications unit labor requirements have declined substantially, with the computer doing in a few hours the work dozens of employees formerly turned out in one day, the adverse effect on employment has been mitigated by several factors. The high rate of attrition which prevailed among the clerical work force required to perform the industry's massive, repetitive data processing tasks has facilitated conversion with minimum dislocation. Moreover, rapid business expansion and advance planning of work force changes appear to have obviated the need for any significant layoffs, and conversion has been carried out mainly by retraining and relocating personnel. Some companies however, have imposed a total freeze on the hiring of clerical workers for protracted periods after computerization to facilitate reassignment of existing staff.

Occupations

A wide range of occupations in the insurance industry has been affected by the application of EDP and related technologies. Because of these innovations, employment in clerical occupations is expected to increase at a slower rate than that envisioned for all employment in the industry. Consequently, clerical workers, who constitute nearly half of the insurance carrier work force, will make up an increasingly smaller proportion of total insurance industry employment by 1985. The demand for and relative importance of a number of clerical positions, including secretaries and typists, keypunch and other office machine operators, bookkeepers, and file clerks, is expected to decline.

However, employment in managerial and technical positions including those related to the planning, installation, and operation of electronic computer systems is expected to increase. Demand will rise for executives and other officials to determine EDP policy, manage data base and teleprocessing networks, and supervise program development and the recruiting and training of computer applications personnel. Employment of systems analysts, programmers, and computer console operators and related computer operating staff is expected to continue to increase. The insurance industry will continue to be receptive to further application of technology to insurance operations since the industry ranks second only to commercial banks in the proportion of its work force engaged in data processing activities.

Employment of persons engaged full time in selling all lines of insurance directly for the carriers (excluding general agents and brokers) is not expected to keep pace with the rapidly expanding volume of sales, primarily because of the increasing number of policies sold to groups and the increasing sales of policies which cover several perils previously covered by separate policies.[8]

As indicated earlier, occupations in clerical fields have been those principally affected by technological change; these include file clerks, keypunch operators, and typists. Although the insurance industry will continue to employ substantial numbers of young high school graduates, many of them women, computerization of practically every mechanical operation is expected to reduce the availability of low-skilled, entry-level clerical positions.

Adjustment of workers to technological change

The further diffusion of computer and related technology in the insurance industry is not expected to bring about major displacement. In most cases, the initial impact of the transition to new technology in data processing operations has been slight because of the increased workload entailed in the conversion. Often, a special department was established during the early stage of the changeover to handle the corollary personnel problems. Moreover, as already indicated, a high degree of attrition of clerical workers—the occupational group most affected by new technology—has eased the transition from manual operations to electronic data processing and made layoffs unnecessary. Continuous industry growth has permitted absorption of displaced personnel in all categories, and coordinated retraining and relocation by the employers have reduced dislocations to a minimum.

Relatively few employees affected by new technology in the insurance industry are union members. The principal union in the insurance industry, the Insurance Workers International Union (IWIU), thus far has concentrated on organizing insurance agents (salespersons), and this has been the category least affected by technological innovation. In late 1976, the IWIU negotiated to organize the clerks of one of the largest insurance carriers. The Office and Professional Employees International Union also has organized in the industry.

The very few union contracts in effect in the industry incorporate specific provisions relating to technological displacement. One such provision which provides job security for employees whose jobs have been affected by new technology reads as follows: "... It is further agreed by the parties that no persons filling jobs within the presently existing collective bargaining unit will be subject to layoff in the event that jobs are abolished or altered by the introduction of data processing equipment, computers or other automated equipment..." For displaced workers, provisions are in effect which provide retraining and preference for any jobs resulting from automation or conversion to electronic data processing.

[8] *Occupational Outlook Handbook, 1978-79 Edition*, Bulletin 1955 (Bureau of Labor Statistics, 1978), p. 763.

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No information is available concerning the effect of reorganizations, mergers, and consolidation of branch offices on employment. There is, however, no evidence that these trends have caused any widespread dislocation.

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Technology and Labor in Metalworking Machinery

A. Harvey Belitsky

Summary

The metalworking machinery industry is rapidly increasing the application of the numerically controlled (NC) machine tool. NC machines accounted for an estimated 30 percent of the value of machine tools installed in the metal-cutting machine tool sector in 1979. Increased diffusion of NC is expected in the 1980's in response to a host of economic conditions, including the advanced age and low productivity of the machine tools in use, the need to meet increasingly precise and complex requirements for machined parts, and the shortage of skilled workers.

While utilization of NC machine tools is likely to increase steadily among the industry's large and medium-size plants, the many small shops which manufacture simple parts will still rely heavily upon manually operated machine tools. Other, more sophisticated technologies such as machining centers (multifunction NC machines), controls utilizing sensors, and NC by computer are also economically feasible, principally for the larger plants. Complex microprocessors, which have fallen sharply in price, permit firms of all sizes to use various intermediate technologies which are not as sophisticated as NC. In general, these technologies increase output per employee hour, improve quality, and reduce occupational skill requirements.

Although definitive measurements of productivity for the industry as a whole are not available, very small productivity improvement in 1960–78 is suggested by an average annual rise in output of about 2 percent and in employee hours of less than 1 percent. Wide swings in output—with associated lags in adjustment of hours—and aging equipment are major reasons for the industry's comparatively low productivity growth rate.

While the industry's dollar outlays for new plant and equipment rose by nearly two-thirds from 1966 to 1978, expenditures in real terms did not surpass the 1966 peak. Real expenditures rose to a comparatively high level in 1974, declined in 1975, and then rose in the succeeding 3 years. They have generally continued to increase, and this may enable manufacturers to compete more effectively with imports for the large tooling requirements of automobile, commercial aircraft, and defense-related manufactures.

Employment in the industry stood at the relatively high level of 371,500 persons in 1980. The average annual increase from 1960 to 1980 was 1.4 percent (about the same rate as for all durable goods manufacturing). The outlook for employment growth from 1980 to 1990 is in the range of 0.8 to 3.8 percent (average annual rates) as projected by BLS, based on alternative versions of economic growth. Increases are projected for virtually all of the industry's occupational groups, but the number of craft workers is expected to grow only half as rapidly as the number of operatives. A shortage of skilled workers could remain a principal obstacle to expansion in the metal-cutting machine sector for at least the immediate future.

Reprinted from BLS Bulletin 2104 (1982), *Technology and Labor in Four Industries.*

Industry Structure

This study examines the metalworking machinery industry as a whole (SIC 354) and three major sectors within the industry: Metal-cutting machine tools (SIC 3541); special dies and tools, die sets, jigs and fixtures, and industrial molds (SIC 3544); and machine tool accessories and measuring devices (SIC 3545). Reference is also made to metal-forming machine tools (SIC 3542). The other metalworking sectors not covered in this study are: Power-driven handtools; rolling mill machinery and equipment; and such machinery as gas cutting and welding equipment.

Some characteristics of this industry tend to limit productivity growth. An estimated three-fourths of the industry's output is in batches of less than 50 pieces. This holds true particularly for the machine tool makers, who often produce special machines for their customers, and for the tool-and-die firms, which frequently produce one-of-a-kind parts. Moreover, establishments in metalworking are comparatively small and highly specialized. Such firms often find it economically unfeasible to invest in new equipment. For example, the tool-and-die sector of the industry (SIC 3544) is made up of 7,100 establishments, averaging only 15 employees. In comparison, the average size of all manufacturing establishments is 55 employees. Additionally, the sharp fluctuation in industry output over the course of the business cycle tends to reduce productivity growth.

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Technology in the 1980's

Numerical control (NC) of machine tools is the most significant new technology introduced in the metalworking industry in the past 25 years. It has experienced substantial and frequent changes in concept and/or design. However, some metalworking firms are investing in intermediate technologies, i.e., technologies which are not as sophisticated or expensive as NC, but which nevertheless improve productivity. These include digital readouts and manual-data-input controls which are applied largely to conventional machine tools. Innovations have also taken place in management techniques and cutting-tool materials. The major technologies, their diffusion, and their labor impact are discussed in more detail below and are presented in table 2.[1]

Numerically controlled machine tools

Numerical control (NC) involves the automatic control of a machine tool's movement by an electronic controller or special computer which reads instructions in digital form. NC tools are more productive than manually operated tools. They reduce setup time; consequently a higher proportion of working time is spent on cutting. The need for costly jigs, templates, and other tooling devices is eliminated. NC tools can produce parts with greater precision and uniformity, thereby further saving machining time and minimizing scrap losses. NC may make possible the production of complex parts that could otherwise not be turned out, or only at great cost; and the process permits engineering changes on a part by merely changing portions of the input program.

NC enhances managerial control by predetermining and coding every stage of machining onto a control tape. It becomes possible for managers to plan more accurately such operations as machine loading and shop scheduling, and it is much easier to predict labor and machine requirements.

NC provides the opportunity to attain some automation in the small batch production which characterizes this industry. The innovation may be more fully appreciated by characterizing NC as a manufacturing system, and not merely a means to control a machine.

Despite the advantages of NC, only about 3 percent of all metal-cutting tools in the metalworking industry in 1976–78 were NC.[2] However, they accounted for a much larger proportion of output. Another indication of the importance of NC is the value of recently installed NC machines. In the metal-cutting machine tool sector, value of shipments was estimated to be 30 percent of all machine tools installed in 1979.

The reason for the lack of diffusion of NC throughout the metalworking machinery industry is the small size of the majority of the firms; they have limited funds for investment in this comparatively expensive technology. Although NC is intended for small batch operations, the risk of investment may be too great because of the volatility of demand for the industry's products. Moreover, firms producing simple parts are unlikely to utilize NC. In addition, NC is not feasible, technically, for some machining methods, such as broaching. It is also interesting to note that surveys disclose that only a few of the general managers in firms without NC fully understood its workings.[3]

Currently, except for a small number of comparatively large firms which use advanced sophisticated NC, most machine tool shops still rely heavily upon skilled workers working on conventional tools. Nonetheless, numerous modest-sized contract tool-and-die shops—also referred to as contract tooling and machining shops—have adopted NC because they do a significant amount of precision machining.

However, if, as expected, NC replaces a large proportion of conventional tools in the 1980's, it could have considerable impact on the metalworking industry. The application of NC should be accelerated by shortages of skilled workers and by the growing need for parts of greater precision. Adding urgency is the steadily increasing demand for variety and versatility in products.

Firms which introduce or expand their use of NC can experience pronounced savings in labor and material. A study of over 350 companies[4] disclosed direct and indirect savings of NC over manually operated tools. Reduced machining time ranged from 35 to 50 percent. Indirect savings of 25 percent or higher were found for material handling, scrap, and inspection. A majority of firms did not even have higher outlays for NC programming if "process planning" on conventional machines is taken into account.

With the introduction of NC, the occupational composition of the work force generally changes. The number of machine operators is likely to decline for a given level of production, since one person can often operate two NC machines. In many cases, skill requirements are reduced. For example, operators no longer need to interpret a blueprint in selecting machine settings. On the other hand, they must be perceptive to a malfunction. Some firms try to enhance the duties of the operator of a very expensive NC machine to make the job

[1]This study does not include the more than 20 technologies that are identified as nontraditional machining processes, although production and application of some of these processes are increasing. Two of these are electrochemical machining and electrical discharge machining. Electrical discharge machining is used widely in tool-and-die shops.

[2]"The 12th American Machinist Inventory of Metalworking Equipment 1976–78," *American Machinist,* December 1978, p. 136.

[3]Edwin Mansfield and others, *Research and Innovation in the Modern Corporation* (New York, Norton and Company, Inc., 1971), pp. 201–202; George P. Putnam, "Why More NC Isn't Being Used," *Machine and Tool Blue Book,* September 1978, pp. 100–101.

[4]Donald N. Smith and Lary Evans, *Management Standards for Computer and Numerical Controls* (Ann Arbor, University of Michigan, 1977), pp. 185, 192, 212, 214, and 222.

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attractive to a skilled machinist. The new position of programmer required with NC is being filled in a growing number of firms by skilled machinists who have received supplementary training. A somewhat larger number of maintenance personnel may be required, and their skill requirements are higher, calling for special training. In general, NC machinery is operated in two or three workshifts, without comparable labor additions on the later shifts.

Numerical control by computer

According to some experts, the combination of the computer with NC in small batch production compares in impact to the introduction of the assembly line and interchangeable parts. Software advances in the late 1960's made it possible for a computer to convey numerical data directly to a machine control unit, thereby eliminating the need for a special control system to operate a machine tool by tape commands. Computer NC (CNC), first with minicomputers and later with microcomputers, made it possible to operate one or more machines and even to connect to larger computers. CNC eliminates the problem of the constant redoing of tape. Also, workpiece program data can be changed in the control system without the necessity for reading an entire program tape. A computer can also keep track of the time each machine tool is in use.

A significant proportion of the NC units in the metalworking industry are the CNC type. Costs of electronic controls have declined so sharply in recent years that some CNC units are competitive with tape-driven control units and are economically feasible for small and medium-size firms. Whereas minicomputers accounted for 50 percent of the cost of a CNC tool in the late 1960's, they now account for less than 20 percent. All the reasons for the lack of diffusion of NC apply even more to CNC. And direct numerical control (DNC), in which a central computer may control up to 100 or more machine tools, is currently used by only a few of the larger toolbuilders in the metalworking industry.

The principal new job classifications arising from the use of CNC are computer programmers, electronic maintenance personnel, and, in some firms, systems analysts. Personnel skilled in preventive maintenance assume great importance with CNC, and machine problems require a multiskill approach.

Machining centers

Machining centers are more elaborate and costly than basic, single-purpose NC. The centers may have automatic tool-changing systems for selecting among 20 to 100 tools that bore, drill, mill, and tap. With rotary heads and tables, a center can work on many surfaces of a part in a single setup. The centers substantially improve managerial flexibility. Moreover, they raise productivity because tool changing is less than on basic NC; one operator may control several machines. While NC may be most suitable for low-volume metalworking shops, a machining center can be justified whether the volume of parts is small or large.

Nevertheless, this technology has only been minimally adopted by the metalworking machinery industry. There are many reasons for this slow acceptance, including high initial cost, simple products which are unsuitable for machining centers, and lack of managerial knowhow.

Adaptive controls

Adaptive controls utilize sensors that automatically control such factors as vibration, tool wear, tool or workpiece deflection, and cutting temperatures. Such sensors can be integrated within an NC controller, or they can operate with conventional machine tools. Although the technology has been available for about 20 years, the application of these controls in metalworking machinery is limited to large shops. Utilization by small shops will depend upon development of improved sensors, their cost effectiveness relative to the availability of skilled workers, and the type of work performed.

Reported improvements in productivity in currently available controls range from 20 to 40 percent, with largest gains when a part requires diverse cutting conditions and the material is hard to machine. Besides improved machining time, scrap and cutter breakage are reduced.[5]

Sensory devices tend to reduce worker skill requirements because they assume many functions traditionally performed by the operator. These devices help to standardize unit labor time. While machining time on an identical part can vary by over 30 percent for different operators, adaptive controls virtually eliminate the differences.

Computer-aided design and manufacture

Computer-aided design and computer-aided manufacture (CAD/CAM) constitute a system which utilizes computer-controlled methods to unite several technologies. Computers are used to assist in developing designs for products to be manufactured (CAD). CAM, among other things, directs numerically controlled machines and automatically guides workpieces among machines on computer-controlled material handling systems. CAD/CAM is influenced by continuing improvements and applications in various phases of manufacturing, including: Assembly with industrial robots; adaptive control; systems to monitor maintenance; and systems to inspect parts automatically. The total impact on productivity and the work force is substantially greater than that of any single technology.

Currently, only the largest machine tool manufacturers utilize CAD/CAM. Its diffusion to medium-size firms will continue to be severely limited by cost and lack of technical expertise.

Higher productivity resulting from adoption of CAD/CAM is associated with the shift of workers to more skilled jobs

[5]D.N. Smith and L. Evans, *op. cit.*, pp. 123, 129, 151.

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and the reduction in the number of lesser skilled jobs. Skilled machinists continue to be needed. The number of drafting personnel is reduced because of less need for extensive lettering and layouts. Some workers have to be retrained for new tasks associated with computer terminals. In addition, worker involvement in decision-making will increase although it will be informal, unlike the practice in some other industries.[6]

Intermediate technologies

There are other technologies being introduced into the industry which are not as sophisticated or expensive as NC, but which improve productivity.[7]

Digital readout (DRO). This device enables a machine operator to position the moving portion of a machine tool more rapidly and accurately. A major change in the DRO followed the introduction of an electronic display panel separate from the metering component. A measure of automatic control is added to almost any manually operated machine, although readouts can be used for verification on NC tools, too. The DRO also enables an operator to change a cutting machine from inch to metric measure by flipping a switch; this is the most economical way of providing certain machines with metric capability.

Increases in efficiency result from fewer operator errors and faster machining cycles. Shop efficiency is also raised because less time is required for setups, repetitive tasks, and inspection. The devices decrease positioning times by up to 80 percent.[8] Although machine setups require highly skilled machinists, operators need less training than previously to carry out a job with the aid of a DRO. Also, operator fatigue is reduced.

The use of DRO's is expanding among machine tool builders and is already widespread among tool-and-die shops. DRO manufacturers anticipate 25-percent yearly growth in sales to the metalworking industry for several years. Major improvements on some DRO's since their introduction about 15 years ago can make programming easier for operators. DRO's can be installed on existing machines and are also relatively reasonable; the payback period is usually considered to be less than 1 year. Consequently, they are feasible for the job shop which cannot afford NC

Manual-data-input control. Manual-data-input (MDI) control of machine tools is more sophisticated than the DRO. Both types of controls inform an operator of machine position, but the MDI also enables an operator to change the machine's position automatically, reducing further the chance of error. Many MDI's can be transformed into NC systems by inserting a tape reader; most current NC systems contain editing capabilities to accept programs manually. MDI usually controls simpler machines and turns out simpler workpieces than does NC. Further, some firms do not want or may be unable to add NC machines. A major difference is that an MDI machinist (and not a programmer, as with NC) usually plans and enters the program for a part.

Increased use of MDI in recent years by the metalworking industry has been stimulated by substantial improvements in microcircuit technology and declining costs compared with other controls. A separate programming department is not needed with MDI, and it can be applied in large as well as small shops. While precise data on the utilization of MDI are unavailable, its use is spreading among machine tool builders, and even more rapidly in the contract tool-and-die shops.

Higher labor productivity and improved product quality are credited to MDI. In addition, MDI can help alleviate the shortage of skilled workers because a machine operator may be able to tend two machine tools. Also, some MDI's utilize "shop language" for programming so that a moderately skilled machinist can use the programming language after brief training.

Cutting-tool materials

Improved cutting-tool materials can play a substantial role in the application of highly productive, advanced technologies. The performance of a $250,000 NC machine tool depends on the cutting capability of a $30 end mill. Firms which can utilize the improved tool materials can more efficiently satisfy material and quality specifications of customers. The new cutting-tool materials improve productivity because, unlike older materials, they do not wear out as fast and thus do not have to be changed as often.

Such new materials as coated carbides, polycrystalline diamonds, and special ceramics are being used in place of tungsten carbide. Applications of the relatively long-lasting coated carbides will continue to increase because of sizable price increases for tungsten. According to an industry analyst, the coated carbides will increase from a current application of some 15 percent to at least 25 percent of cutting-tool materials used by the metalworking machinery industry in 1985.

Group technology

Group technology (GT), a management technique, can be as important to productivity as new machines. It involves the grouping of parts on the basis of similar shapes and/or processing requirements. GT revises the belief that small batch manufacturing consists of making distinctive parts from design to end-product. Marked savings are attributed to GT as a result of improved

[6] *Proceedings, Eighth Annual Tri-Service Manufacturing Technology Coordination Conference,* Arlington, Texas, Nov. 8–12, 1976, p. 170.

[7] Programmable controllers, normally associated with mass-production industries, and programmable hand calculators are also intermediate technologies which have had successful applications in small batch manufacturing. See National Center for Productivity and Quality of Working Life, *New Technologies and Training in Metalworking,* Summer 1978, pp. 4–7.

[8] George Schaffer, "Digital Readout Systems," *American Machinist,* May 1979, p. SR-4.

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production scheduling, reduced inventory, and greater efficiency in machine loading. Design rationalization and reduced, as well as more efficient, setup and tooling are also credited to the process.

GT also could reduce skill specializations which often exist in medium-size and large machine tool shops. Unlike the usual practice in Europe and Japan, only a small proportion of the U.S. metalworking firms which have introduced GT have broadened the skill requirements of their work forces.

Small firms cannot afford the sophisticated effort needed to install GT, and it is used by less than 20 percent of all toolbuilders. Tool-and-die shops do not utilize GT as such, but elements of it are present in shop layout procedures among firms engaged in precision machining and the manufacture of machine tools.

Table 2. Major technology changes in metalworking machinery

Technology	Description	Labor implications	Diffusion
Numerically controlled machine tool (NC)	Tool is controlled by instructions received from tape, punched cards, plugs, or other media. Allows rapid change to new product designs; permits stricter tolerances for parts; and reduces setup time. Useful for small batch production, because parts can be machined by merely changing tapes and resetting tool.	Estimated reduction in machining time of 35–50 percent; typically used two or three shifts. Reduces unit requirements for machine operators; requires less skill than manually operated tools, creates new job of programmer; requires more broadly trained maintenance personnel.	Three percent of all machine tools in metalworking are NC, but they account for a much larger proportion of total output. In metal-cutting sector, the value of NC machines is estimated at 30 percent of all machine tools installed in 1979. Considerable growth in the number of NC tools and their share of total output is expected in the 1980's.
Numerical control by computer (CNC)	On-board computer stores and conveys information directly to NC control unit; utilizes latest microprocessor technology.	Same labor implications as NC but, unlike NC, may require computer personnel. Saves time in reprogramming to remove errors or make design changes. Requires maintenance personnel with electronic skills.	Significant proportion of NC machines; mainly limited to larger and medium-size machine tool shops. Expected to increase substantially in the 1980's as result of cost reductions in electric controls; some smaller shops will introduce it.
Machining center	An automatic tool changer makes the center a multifunction NC machine. Each center is equivalent to several machines, each having a specific function.	Raises productivity by permitting operations on many surfaces of a part in a single setup. Operator may control several machines.	Accounts for a small but growing percentage of machine tools in larger plants, but a disproportionately large share of the industry's output.
Adaptive control	Automatically controls feed rate to reduce or eliminate such factors as vibration, tool wear, and cutting temperatures, and alerts operator. Can be used with conventional tools or with NC.	Raises productivity in machining through substitution of sensors for workers' own perceptions. Reduces skill requirements.	Used by large plants. Utilization by small shops will depend upon development of improved sensors and their cost effectiveness relative to the availability of skilled workers and also the type of work performed.
Computer-aided design/computer-aided manufacture (CAD/CAM)	Computers are used to develop designs for products to be manufactured (CAD). CAM directs numerically controlled machines and automatically guides workpieces among machines on computer-controlled handling systems.	Reduces need for low-skilled operators; increases requirements for higher skilled workers.	Used by large machine tool manufacturers only; diffusion to medium-size firms will be severely limited by the technology's cost.
Digital readout (DRO)	A device is applied to movable portion of a machine tool to measure its actual movement; can provide some automatic control; measurement appears on a display unit.	Operator efficiency and accuracy are enhanced during the positioning phase of the machine cycle. Operators are trained in less time and fatigue is reduced.	Use is limited but increasing among machine tool builders; already widespread among tool-and-die shops. Producers of DRO's expect a 25-percent annual growth in their sales to the metalworking machinery industry in the next several years.
Manual-data-input control (MDI)	Enables an operator to change the position of a machine automatically; also identified as "operator-programmed NC."	Machinist can plan and enter part programs; possible in "shop language." Training period shorter than for NC programming.	Precise data on utilization are unavailable, but its use is spreading among machine tool builders and even more rapidly in the contract tool-and-die shops.
Cutting-tool materials	Durable new materials, such as coated carbides, polycrystalline diamonds, and special ceramics more efficiently meet continued increases in machining speed.	Reduce labor requirements somewhat because tools do not have to be changed as often.	Tungsten carbide expected to remain the major material, but coated carbides may increase from current 15 percent to 25 percent of all cutting-tool materials in metalworking machinery in 1985.
Group technology (GT)	Management skills used to reduce small batch operations. Involves the grouping of parts on the basis of similar shapes and/or processing requirements. Workers may perform a wide range of tasks.	Improves efficiency and quality of output. Workers may broaden skills and replace narrow specializations.	Used by some large machine tool builders; elements of GT likely to spread slowly to smaller builders and tool-and-die shops.

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Output and Productivity Outlook

Output

The metalworking industry has undergone sharp fluctuations in output in response to the business cycle, typical of the experience of other capital goods industries. Although reliable output data are not available for the total metalworking machinery industry, Census value of shipments data adjusted for price changes (used as a crude measure of output) suggest an average annual growth rate of about 2 percent in 1960–78. Output grew very rapidly (8–9 percent a year) in the period 1960–67. However, in 1967–73, average output declined by about 2 percent and, in 1973–78, the average rate of decline was still about 1 percent, reflecting the 1970 and 1975 recessions. Although later data are not available, there is evidence that some sectors of the industry are recovering in response to the large tooling requirements of the automobile, aircraft, and defense industries.

While all sectors had impressive rates of growth in 1960–67, the pattern of the sectors varied considerably in the next decade.[9] Metal-cutting tool output advanced at a double-digit rate annually (12.0 percent) in 1960–67, and then experienced a very steep decline (8.9 percent annually) in 1967–73. However, in 1973–80 a moderate rate of recovery (2.7 percent) occurred, as output grew strongly after the 1975–76 recession. A similar rise and fall, but not as pronounced, occurred in metal-forming output in 1960–67 and 1967–73. However, in the succeeding period, 1973–80, metal-forming output declined—more steeply than in 1967–73. As in the recession years of 1975 and 1976, output again fell sharply in 1980. Nevertheless, in certain sectors, e.g., metal cutting, delivery time for some orders was as much as 2 years.

One explanation for the decline in metal-cutting output over the longer period of 1967–79 is the tardiness of customer industries in buying new tools. The aging of the machines in the U.S. economy has been a long-term problem. The percentage of metal-cutting machines that are less than 10 years old has been declining steadily since the end of World War II; an estimate of 31 percent for 1976–78 approaches the rate at the end of the depression in 1940. Moreover, when all U.S. metal-cutting and metal-forming tools are combined and compared with tools in six other major industrial nations, the United States had the smallest percentage of machines less than 10 years old and the highest percentage of machines over 20 years old.[10]

[9]Output data for the metal-cutting (SIC 3541) and metal-forming sectors (SIC 3542) are weighted output measures developed by BLS for 1958 to 1980. The data for all other sectors, as well as the entire industry (SIC 354), are deflated Census value of shipments data; latest year, 1978.

[10]"The 12th American Machinist Inventory of Metalworking Equipment 1976–78," *American Machinist, op. cit.*, pp. 133, 135, and 137. The data for the six foreign industrial nations are based on the most recent studies in each country, ranging from 1973 to 1978.

Of major importance is the change in the mix of output as the proportion of numerically controlled tools has increased. It is estimated that, in 1973, about 40 percent of the value of shipments of NC milling machines and machining centers plus comparable conventional machine tools was accounted for by NC machines; the percentage rose to 66 percent by 1977, according to estimates of a consultant to the industry. In the case of NC lathes and conventional lathes, the estimated rise in NC shipments was from 32 percent of the total value in 1973 to 52 percent in 1977. Because NC is considerably more productive, fewer machines are required for a given amount of production.

To some extent, output growth in the industry has been held back by the lack of skilled workers to accommodate to periods of higher demand. While the industry has undertaken considerable worker training in strong growth periods, numerous trained skilled workers had to be laid off when slumps in production took place. Some of these workers left the industry for more stable jobs in other industries; this was especially the case for workers who experienced more than one long spell of unemployment.

Foreign trade. Traditionally, the United States has enjoyed a comfortable advantage in the export of metal-cutting machines. In 1958–65, the value of exports was at least three times as large as the value of imports. Although a trade advantage was maintained in the years 1966–76, it was no longer as large as in earlier years, and in only 2 years (1970 and 1971) was the trade advantage as high as 2 to 1.

In 1977, imports of metal-cutting machines exceeded exports for the first time. Although exports of cutting machines continued to average more in the 1970's than in the 1960's (83.5 percent higher), the rise in imports was considerably more rapid (4.2 times as high in the 1970's). In 1978, the continued deterioration in the trade position of metal-cutting machines offset the favorable trade balance of the metal-forming sector for the first time, and the trade imbalance rose even higher in 1979.

U.S. machine tool manufacturers have not been competing successfully with foreign producers in domestic markets, as is evident by the increase in the import penetration ratio, that is, imports as a percent of apparent consumption (imports plus domestic production, excluding exports). This ratio more than doubled between 1972 and 1979, rising from 9 percent to 22 percent, with the biggest jump in 1978. It rose again in 1980. U.S. manufacturers may be unable to recapture a large portion of the imports of conventional machine tools from Japan and Taiwan. As a result, U.S. firms will have to become more competitive with Japan and also West Germany in the production and sale of NC machines, machining centers, and specialized machines.

In addition to the very rapid expansion in imports, the unfavorable balance of trade in metal cutting was also affected by the way in which foreign trading relationships

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in these machines are established. During several prosperous years in the 1960's, machine tool builders did not have much incentive to expand their exports to new customers. Yet, machine exports depend upon the establishment of a long-term relationship. Machine buyers often rely upon the machine makers to service and ultimately even rebuild their machines after several years of usage. In the absence of more commercial ties abroad, U.S. machine tool firms could not take advantage of their excess capacity during the recessions of the 1970's to increase their exports. More recently, the sizable upswing in domestic orders has again been reducing interest in exports, as numerous firms are operating at or near capacity levels, and skilled workers are in short supply. Prospective exporters are also handicapped because their lead times for delivery of new machines are relatively longer than in some other countries.

Productivity

Although a reliable measure of productivity is unavailable for the metalworking machinery industry as a whole, trends can be estimated from available output and employee-hours data. Deflated value of shipments, used as a crude measure of output, increased by about 2 percent annually in 1960–78, while the rate of change in employee hours was less than 1 percent for the same period (chart 6). These data suggest that the productivity growth rate averaged only 1–2 percent annually in the 1960–78 period. While productivity (estimated as above) grew moderately from 1960–67, it rose more slowly in 1967–73 and then edged down in 1973–78.

In the metal-cutting sector, for which a BLS weighted measure is available, productivity growth averaged only 1.2 percent in the 1960–80 period, approximately the rate of growth for the whole industry. While productivity grew at an average of 4.1 percent annually from 1960 to 1967, it only edged up at less than 1 percent from 1967 to 1973, when output dropped about 9 percent. In the succeeding 7 years, 1973–80, productivity showed no growth. While growth was relatively strong after 1976, it just offset the recession declines.

Traditionally in capital goods manufacturing, which is highly cyclical, there is a lag in the adjustment of hours to output changes. In this industry, there is often considerable reliance on changes in the overtime component of employee hours in order to adapt to the wide shifts in output. This is especially evident in the metal-cutting sector. Metal-cutting production has characteristics that are not present to the same degree in other industries, particularly labor intensity, high skill needs, and the considerable time and cost to train workers. Moreover, there is a shortage of skilled workers. Consequently, during an upturn, overtime hours are increased; in a downturn, firms keep as many of their employees on the payroll for as long a period as they regard practicable, but reduce overtime.

In contrast, the products of the accessory sector, which include perishable tools and various attachments and accessories for machine tools and other metalworking machinery, enable these manufacturers to benefit from a production process of typically shorter time frames and larger batches than in machine tools. The accessories firms stock numerous standardized products to accommodate anticipated industry demand. Moreover, while the accessory sector needs skilled instrumentmakers to produce measuring devices, the bulk of its output requires a relatively less skilled work force than does metal cutting. Therefore a downturn in the accessory sector output is more likely to be matched by a comparable decrease in employment than in the metal-cutting sector.

The machine tool builders have less flexibility in the adjustment of employment. This can be attributed to the length of time required to complete orders for metal-cutting machinery and the limited standardization that is possible in its production. Such machinery is usually only manufactured when purchase orders are in hand and requires several months to make. The special machines that are manufactured in this sector are necessarily made in small production runs. Even many of the so-called universal machines are in some way modified to meet individual buyer specifications, thereby ruling out some of the economies associated with longer production runs.

The industry has made some attempt to overcome the obstacle of small batch production to improve productivity in the machine tool sectors. For instance, construction standards have been developed over a 20-year period by NC committees of the Electronic Industries Association to enable greater output of standard components and interchangeable subassemblies. In addition, standards have been revised to accommodate advances in technology, such as the capability of computer NC systems to handle manual data input.

Aging machinery is a factor which limits productivity growth in firms throughout the metalworking machinery industry. It has been stated that many of the rather old manually operated tools in use actually cut metal for much less than 10 percent of the time a workpiece is in a batch production shop. Considerable time is involved in setting up to make a part, or parts are being loaded or unloaded, or tools are being changed. As noted in the next section, an upswing in investment in new plant and equipment was underway in the metal-cutting sector. Future data may better reflect the installation of newer, more productive machines, because, in general, optimization of new plant and equipment can be a lengthy process.

Investment

Capital expenditures

Real capital expenditures[11] by the metalworking machinery industry in 1978 were less than 80 percent of peak levels in 1966, although in current dollars they rose by nearly two-thirds. The cyclical volatility of capital outlays

[11] Deflated by implicit price deflator for metalworking machinery.

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in this industry is pronounced. Expenditures (in constant dollars) rose almost steadily to their highest level in 1966, moved down rapidly in 1970, and plummeted in 1971 to reach the lowest level since 1963. After rising to near peak levels in 1974, expenditures fell sharply again in 1975. Although they recovered in succeeding years, the peak outlays of 1966 were not surpassed.

Approximately the same pattern is reflected in the three major sectors of the metalworking machinery industry. In metal-cutting machinery, peak expenditures (real) occurred in 1967. In 1978, over a decade later, real expenditures were less than 65 percent of the peak. Machine tool accessories and measuring devices attained their summit in real capital expenditures in 1966–67; by 1978 they were only about 85 percent of the level for those 2 years.

The third major sector—special dies and tools, die sets, jigs and fixtures, and industrial molds—which typically accounts for well over one-third of capital expenditures in metalworking machinery, surpassed its 1966 peak in expenditures in 1974. More pronounced, however, than in the other sectors, was the decline in outlays in 1975, to half of those of the previous year. By 1978, real outlays were about 80 percent of the peak.

No more recent Census data are available, but, according to industry reports, outlays by the machine tool builders were rising sharply in response to increasing demand, noted earlier, by the automobile, aircraft, and defense industries. Capacity of this sector may be greatly enlarged in the early 1980's. The more productive, automated machinery being installed may improve the industry's competitive position vis-a-vis foreign imports.

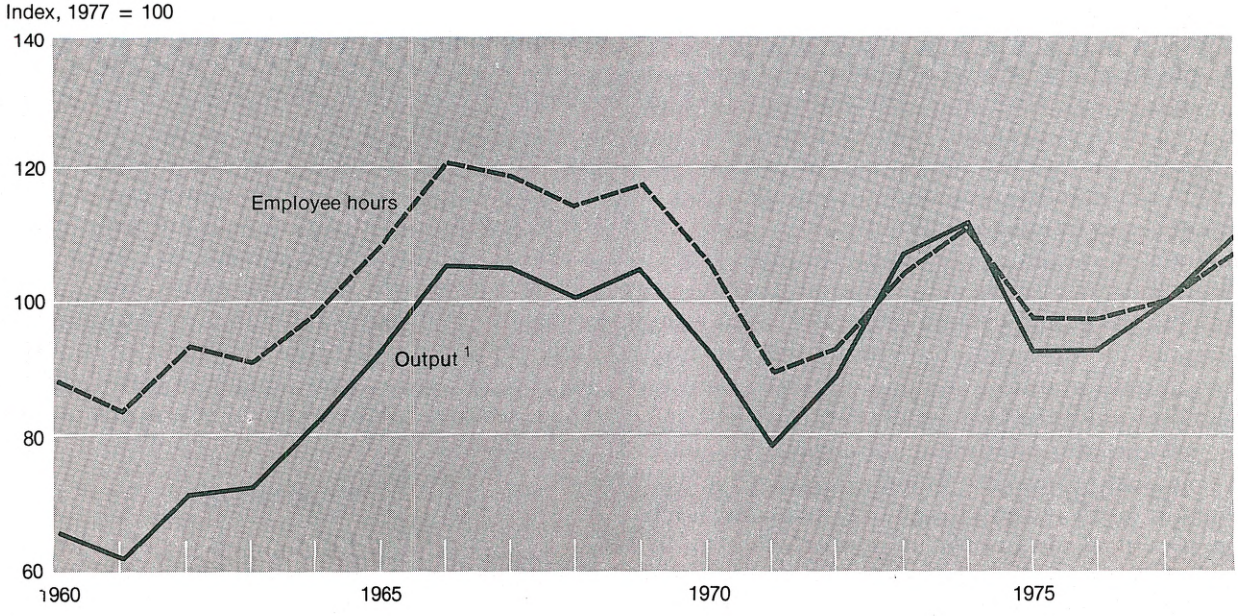
Research and development

A few of the relatively large machine tool builders have undertaken research as well as development. However, in general, most of these firms are in development only. For example, large machine tool makers are involved in the development of improved computer controls for machine tools. To some extent, large companies outside the industry have undertaken R&D at least in part to improve machining standards in their own work. For instance, a firm pioneered in the recent development of a cutting tool with polycrystalline diamond material.

Some joint interindustry development has taken place, including the pooling of development costs by several machine tool builders and an automobile manufacturer in order to increase the speed of lathes. However, there is currently relatively little in the way of joint efforts by government, industry, and labor compared with those in some countries, notably Japan.[12]

[12]Comptroller General of the United States, *Manufacturing Technology—A Changing Challenge to Improved Productivity*, June 3,1976, pp. 74, 88–89.

Chart 6. Output and employee hours, metalworking machinery, 1960-78



1 Deflated value of shipments, unpublished data.
Sources: Bureau of Labor Statistics and Bureau of the Census.

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Considerable R&D effort has been directed toward standardization. Whereas once there were more than 30 adapters in use by machine tool builders, the industry is moving toward more universal use of an adapter developed by a large machinery manufacturer. The adapter makes possible substantial reduction in cutting-tool inventories and is considered particularly useful for small firms with NC machines.

The National Bureau of Standards is also advancing the pace of innovation within the industry. The Bureau has research underway to improve the ability of NC and industrial robots to work together. The Bureau is also trying to improve the adaptability of robots. According to a Bureau research analyst, the largest share of robot applications during the 1980's will be in loading and unloading machine tools.

Employment and Occupational Trends

Employment

The industry's employment increased at an average annual rate of 1.4 percent in 1960–80, about the same as for all durable goods manufacturing industries. While employment growth averaged 5.1 percent in 1960–67, it declined 3.0 percent annually during 1967–73, but rose again at 2.3 percent annually in 1973–80. For the period 1980–90, three employment projections by the Bureau of Labor Statistics, based on alternative versions of economic growth, fall in the range of 0.8 percent annually (only about half the 1960–80 rate) to 3.8 percent (2½ times the 1960–80 rate).[13] The low-trend estimate for metalworking machinery is only half the growth rate expected for all durable goods by 1990, while the high-trend estimate (Level B on chart 7) exceeds the projected growth rate for durable goods manufacturing.

At 371,500 persons, employment in 1980 was exceeded only during 2 World War II years. After dropping to a postwar trough in 1949, employment rose steadily to 314,000 in 1953, and was not surpassed until the second half of the 1960's. Over the years 1960–80, there were three periods of sharp cyclical fluctuations affecting every major sector of the metalworking industry. Employment hit a low in 1961 and then exhibited strong continuous growth through 1967 when peak levels were attained. Subsequently, the industry reflected the economy's recessions with deep employment declines in 1971 and again, but not as steeply, in 1975 and 1976. Since then, employment has moved up sharply.

As mentioned earlier, overtime hours play an important role in this industry. By expanding and contracting overtime hours of production workers in response to changes in output, employers tend to moderate short-term hirings and layoffs. While this is true for the entire metalworking machinery industry, it is more marked in the metal-cutting sector. Overtime hours in metal cutting during the sector's cyclical peaks and troughs of 1960–61, 1969–70, and 1973–75 ranged, respectively, from 5.5 to 1.9 hours, 6.5 to 1.8 hours, and 7.8 to 1.8 hours (average weekly data). The proportion of production workers to all employees in the industry has not changed significantly in the last two decades. Production workers accounted for 75 percent of all employees in 1960 and 73 percent in 1980. The comparable figures for all durable goods manufacturing industries were 74 percent and 69 percent.

The three largest industrial sectors in metalworking machinery—namely, tool and die, metal cutting, and machine tool accessories—accounted for slightly over three-fourths of the industry's total employment in the years 1960 through 1980, but the metal-cutting sector declined in relative importance. They all exhibited growth from 1960 to 1967, but the tool and die and machine tool accessory sectors grew at faster average annual rates than did metal cutting. In spite of its recent sharp rise, employment in metal cutting has not recovered fully from its low levels of 1971 and 1972, while the other two sectors recovered more rapidly and attained their peaks in 1979 and 1980 (chart 7). Tool and die and machine tool accessories firms increased their share of employment within the metalworking industry from 50 percent in 1960 to 55 percent in 1980. The share of metal-cutting employment declined from 27 percent in 1960 to 21.5 percent in 1980.

Occupations

BLS projects an employment increase from 1978 to 1990 for all but the smallest occupational group (sales workers) in the metalworking machinery industry. Craft workers and operatives, the two largest of the blue-collar groups, each constituted nearly one-third of all employees in metalworking in 1978. While operatives are expected to grow 36 percent by 1990, the increase for craft workers is expected to be about half that rate (chart 8). By 1990, operatives will account for a somewhat larger percent of total employment than in 1978, while the proportion of craft workers is expected to decline slightly.

A major influence on occupational skills and responsibilities in the past decade has been the use of numerically controlled machines. For example, the more rapid growth in employment of operatives is at least partly attributable to the recent expansion of NC

[13]Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. On chart 7, Level A is the low-trend, Level B is high-trend I, and Level C is high-trend II. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review*.

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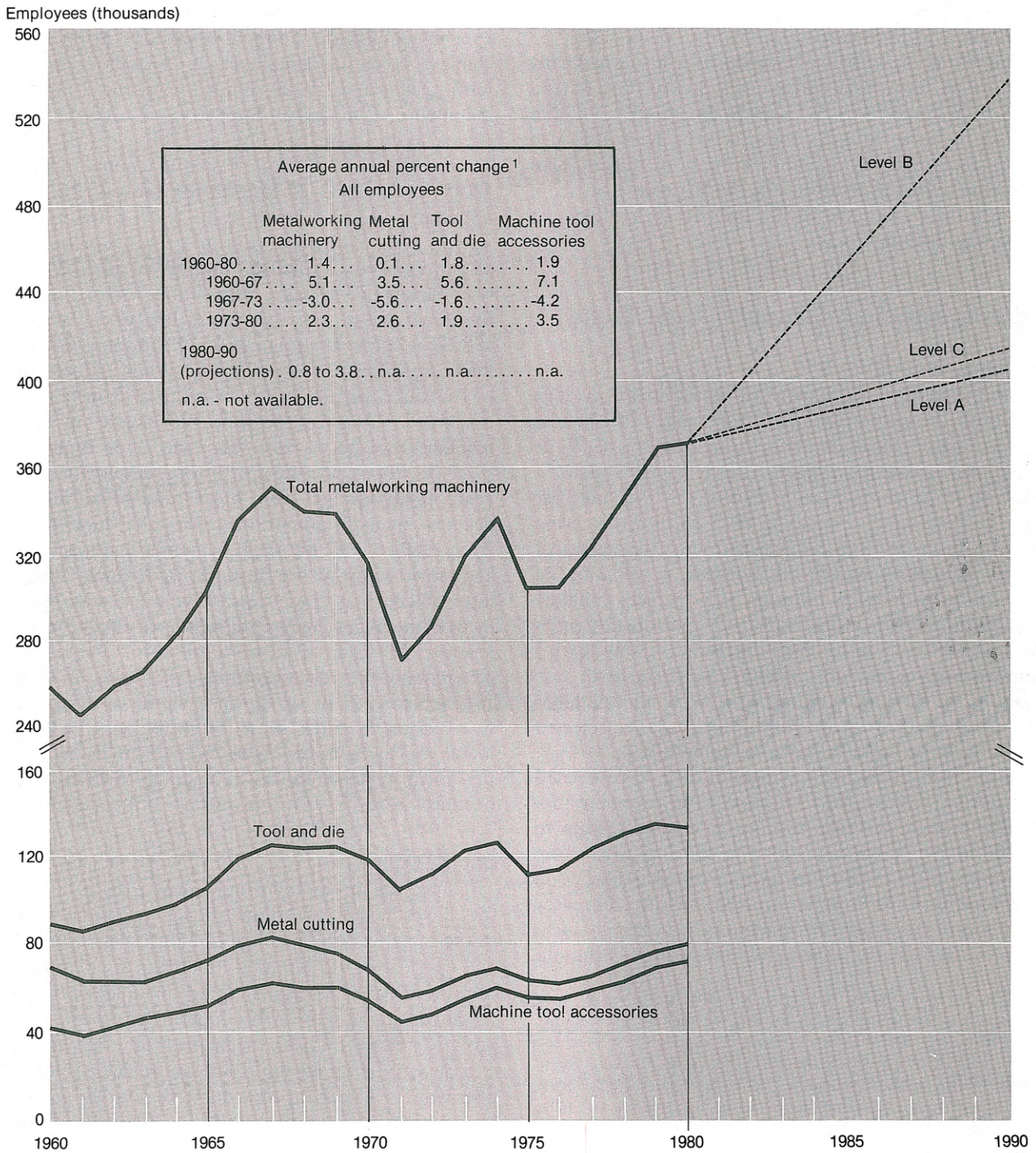
Chart 7. Employment in metalworking machinery and selected industry sectors, 1960-80, and projections for 1980-90



[1] Least squares trend method for historical data; compound interest method for projections.

Note: See text footnote 13 for explanation of alternative projections.

Source: Bureau of Labor Statistics.

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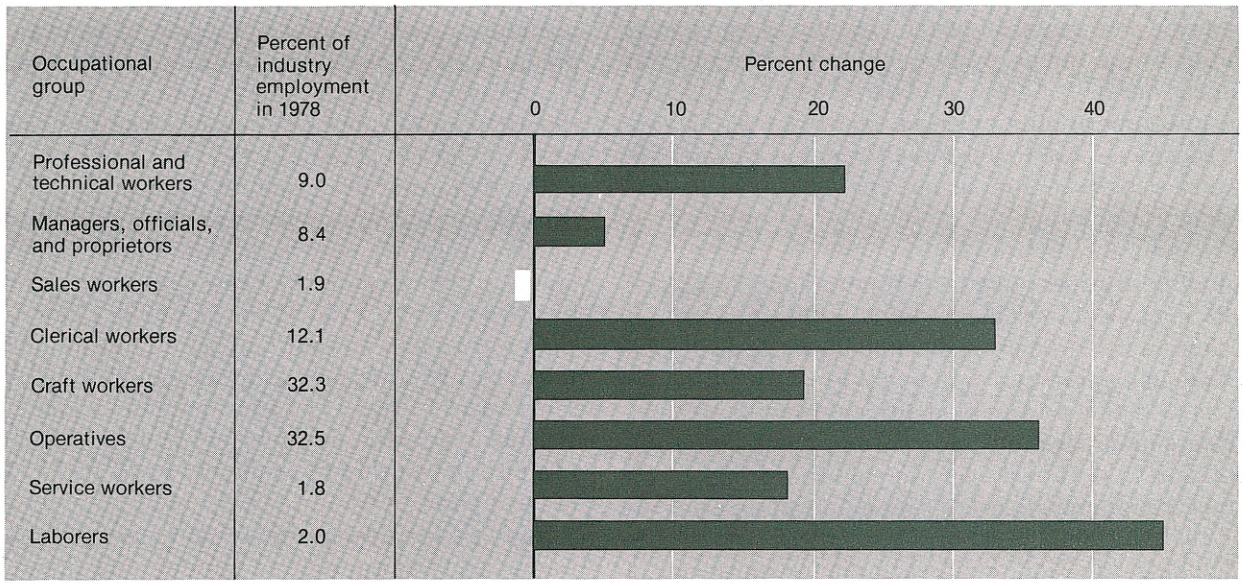
Chart 8. Projected changes in employment in metalworking machinery by occupational group, 1978-90



Source: Bureau of Labor Statistics.

machines and various intermediate technologies. A shortage of skilled workers is a major reason certain firms have turned to NC. Over 800 member firms of the National Tooling and Machining Association indicated that they needed on average a 26-percent increase in skilled toolmakers and machinists.[14] Similarly, the great majority of nonelectrical machinery manufacturing plants responding to an *Industry Week* survey reported shortages of skilled workers; the most pressing needs were for machine operators, mechanics, electricians, and tool-and-die makers.[15]

A study which compared the skills of machinists on NC with those on manually operated machine tools revealed that NC machines are associated with a decline in demand for motor skills and decisionmaking abilities.[16] According to a BLS study, NC operators need less knowledge because tapes are programmed to control speed, feed, and width and depth of cut.[17] At the same time, the study referred to the need for greater conceptual skills on NC machines.

There will, however, be continued need for highly skilled machine operators on the most advanced NC machines. Moreover, the costliness of NC machines and the intricacy of their control systems increase the need for preventive maintenance mechanics trained in electronics with practical knowledge of hydraulics and pneumatics. BLS projects that employment of mechanics, repairers, and installers, a subdivision of the craft worker group, will expand five times as fast as all craft employment.

While employment of professional and technical workers is projected to grow by 22 percent from 1978 to 1990, the projected increase for managers, officials, and proprietors will be only at one-fourth that rate. The former's share of total industry employment will be virtually unchanged by 1990, while the latter's share will decline. Changed skills and responsibilities, also largely related to NC equipment, are occurring for these occupational groups. The competitive structure of the industry and complexity of NC equipment and other technologies require not only knowledge of the new machines but also the capability to organize a shop's production so that the machines are utilized optimally.

[14]National Tooling and Machining Association, *Record,* Vol. 2, No. 5, May 1979, p. 4.

[15]Daniel D. Cook and John S. McClenahen, "Skilled Worker Nears Extinction," *Industry Week,* Aug. 29, 1977, p. 46; also see Michael Marley, "If They Could Clone Skilled Workers," *Iron Age,* Vol. 221, No. 37, Sept. 11, 1978, pp. 36-38.

[16]R.J. Hazlehurst, R.J. Bradbury, and E.N. Corlett, "A Comparison of the Skills of Machinists on Numerically Controlled and Conventional Machines," *Occupational Psychology,* Vol. 43, Nos. 3 and 4, 1969, p. 177.

[17]*Technological Change and Manpower Trends in Five Industries,* Bulletin 1856 (Bureau of Labor Statistics, 1975), p. 42.

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Engineers will remain the dominant occupation for the professional and technical worker group in 1990, with about half the engineers still in the mechanical field. Drafters will remain, by far, the largest single occupation in the technician group. While computer specialists are expected to increase at only half the rate for total industry employment, the number of numerical tool programmers will more than double by 1990, but will still account for less than one-half of 1 percent of the industry's employees. The programmer position on advanced NC tools requires mathematics, the ability to visualize objects and motions in dimensions, and an understanding of cutting and tooling principles.

Adjustment of workers to technological change

Programs to protect the worker from the adverse affects of changes in machinery and methods may be incorporated into union contracts or they may be informal arrangements between workers and management. In general, such programs are more prevalent and detailed in formal contracts. Both formal and informal labor-management arrangements are influenced by the state of the economy and the availability of labor.

Training may be the major factor in the adjustment of workers to technological change in this industry. Officers of leading machine tool manufacturing firms refer to shortages of trained machinists and other technical and skilled workers as a principal obstacle to maintaining high levels of production or increasing them.

Provision for an adequate level of training is complicated by demographic factors. An aging work force is making it steadily harder to maintain a nucleus of skilled workers as many, including tool-and-die makers, continue to retire. To cover the skill shortages, NC tool builders have provided short, intensive training programs in the fundamentals of maintenance to electricians and other skilled workers. Machinists and even experienced machine operators are being trained in programming.

The extent of training provided by employers is not precisely known. In some cases, small firms have taken a multiemployer approach to apprenticeship and other qualifying training. While some form of training is provided by most employers, local union bargaining agreements typically do not refer specifically to training. A BLS survey of structured training in the nonelectrical machinery industries disclosed that only 18 percent of the surveyed establishments provided training in one or more skilled occupations; and only about one-third of the training was for skill improvement, while two-thirds was training to qualify for the job. The survey excluded the most common forms of training, namely, learning through experience and informal training. The survey included metalworking machinery establishments but data for them were not available separately.

Since 1966, the U.S. Department of Labor (DOL) has provided training funds which have been distributed by the National Machine Tool Builders Association. As of fiscal year 1979, trainees hired by the machine tool manufacturers for the DOL program have to be economically disadvantaged persons. The training (including classroom instruction) is conducted on the job site. Typically, the training is in such fields as machine operation, assembly, and machine repair, and the programs run 13 to 16 weeks. More than 14,000 graduates have proven a good screening source for apprentices who can later qualify for more skilled, higher paying jobs requiring further training.

The National Tooling and Machining Association has enrolled over 15,000 persons in their preemployment training program funded by the DOL. The program, which previously consisted of 16 weeks of institutional training followed by 36 weeks of on-the-job training, now is a 12-week program of institutional training only for economically disadvantaged persons. An industry spokesman believes that this program alone is not providing a sufficient number of persons who are qualified for further training in more highly skilled occupations.

Since skilled workers are in short supply, some firms have sought foreign workers. However, the firms do this reluctantly because of the time involved in completing paperwork and securing approval for immigration. A survey in Milwaukee disclosed that the careers of machinist or machine operator ranked rather low with high school students, even though the city is a major machine tool producer.[18] However, some metalworking firms are making greater efforts to attract young people to the industry by enrolling high school students in cooperative programs (involving morning school attendance and afternoon work), much as they have done successfully with engineering personnel.

The International Association of Machinists and Aerospace Workers (IAM) is the major union in this industry. The United Automobile Workers (UAW) and the United Steelworkers of America (USA) are the other two leading unions. Overall, these unions plus several others have organized about one-third of the workers in the industry.

Contract provisions for nine metalworking firms studied by BLS which each employ at least 1,000 workers appear to be representative of the bargaining agreements negotiated by the three leading unions. In general, the prevalence of seniority provisions acts as a measure of job security when technological change takes place. Agreements provide for seniority rights in the event of layoff and for purposes of rehiring. Interplant transfers are quite uncommon. A provision requiring advance notice of layoff is present in a majority of the agreements studied,

[18] J.G. Udell and others, *Skilled Labor in the Milwaukee Area: The Supply, Education, Problems and Opportunities,* Wisconsin Economy Study No. 15 (Madison, University of Wisconsin, Graduate School of Business, July 1977).

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but such notices are generally unrelated to technological change. Nevertheless, some agreements specifically refer to "new equipment" and most UAW agreements deal with "new jobs." Companies in these instances are normally required to consult with the union regarding changes in job description or occupational assignment of the job, and provisions exist for resolving grievances.

Considerable effort by management to improve job security is related to the shortage of skilled workers. The problem is complicated by the cyclical nature of the industry. A Connecticut machine tool builder visited by BLS made the following arrangement: During a 9-month slack period, the firm employed its work force for 3-week periods, and unemployment insurance (UI) payments were secured for the fourth week of each month. (In Connecticut, no waiting period is required for UI payments.)

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Technology and Labor in Motor Vehicles and Equipment

Robert V. Critchlow

Summary

New equipment and manufacturing methods are expected to continue to be introduced in the motor vehicle and equipment industry. Specific innovations which may be applied more widely include electronic computers, improved equipment for automatic assembly, use of plastic and powdered metal materials, numerical control, and improved transfer lines. New technology in some instances is expected to improve quality and achieve productivity gains.

A total of $2.1 billion was spent by the motor vehicle industry for new plant and equipment in 1975, and an estimated $2.4 billion was spent in 1976. These amounts are about three times as much as the 1960 expenditure of $790 million, although the increase would be less in real terms due to increases in plant and equipment prices over the period. The average annual rate of increase in spending was lower during 1967-75 than during the 1960-67 period. Capital expenditures are expected to increase considerably over the next several years in order to produce cars that can meet Federal Government standards for safety, exhaust pollution levels, and fuel economy.

Output per employee-hour in the motor vehicle and equipment industry (BLS data) increased at an annual rate of 3.2 percent between 1960 and 1975. The productivity growth rate in the motor vehicle industry was 3.6 percent annually during 1960-67, slightly above the 3.2-percent average annual rate achieved during 1967-75. Growth in output per employee-hour was particularly strong during 1971 and 1972 as output rose sharply from the 1970 strike-year level in response to very strong demand for cars and trucks. Further productivity growth occurred in 1975 when employment fell more rapidly than output. Productivity gains in assembly, machining, and other production operations are expected as new technology is introduced.

Industry employment rose from 724,000 in 1960 to a peak of 955,300 in 1973, then dropped during the economic downturn of late 1974-75 to 774,100 in 1975.[1] As sales and production improved in 1976, employment rose to 850,600. BLS projections indicate that employment may decline to 808,000 by 1985.

Technological and other changes will continue to alter the structure of occupations in this industry. Demand for managers, sales workers, and semiskilled operatives will increase while declines are expected in the other major occupational groups. Although new technology will reduce unit labor requirements in some operations, industry growth will result in higher long-term employment levels for computer specialists, assemblers, and others who work with new technology. Semiskilled workers will continue to constitute the largest occupational category. These workers are engaged in production operations which generally are the most labor intensive and have potential for further technological change.

Reprinted from BLS Bulletin 1961 (1977),
Technological Change and its Labor Impact in Five Industries.

Technology in the 1970's

Technological changes in the motor vehicle and equipment industry are underway in major phases of production, with productivity gains and laborsavings anticipated. These changes include more extensive use of electronic computers, improved equipment for automatic assembly and inspection, more widespread use of plastics and other lightweight materials, more widespread application of numerical control, and improvements in transfer lines. (See table 5.) Modifications of automobile engines also are underway to meet stricter emission standards and to raise fuel economy.

Electronic computers

Computers are a key technology in the automobile industry, initially applied to business operations such as payroll and bookkeeping records and subsequently extended to an increasing number of research and production operations. According to International Data Corporation, more than 400 computers are in use in the industry, with further growth in computer use expected. Examples of computer applications gaining prominence, and their labor implications, are presented below.

Auto styling and design. Mathematical information representing automobile body surfaces can be stored in a computer memory system. A designer, working with a graphic display terminal, can use this information to design auto

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Table 5. Major technology changes in the motor vehicle and equipment industry

Technology	Description	Labor implications	Diffusion
Electronic computers	The use of graphic display terminals can integrate and speed workflow between design, tooling, and production. Time requirements for R&D work are lowered. Numerous applications in quality control increase productivity of inspection personnel. Computer control of machining and assembly operations may increase production rates and reduce labor requirements.	Employment increases in computer-related occupations such as systems analysts, programmers, and peripheral equipment operators. Declines expected for drafters and keypunch operators.	More than 400 computers are estimated to be in use. Continued growth expected in the number of computers and types of applications.
Machine assembly operations (automated assembly lines)	Automated assembly applications range from tightening bolts to welding car bodies together. Automatic assembly stations are frequently intermixed with manual stations, depending upon the nature of the job.	Reduced labor requirements in semiskilled assembly operations, and increased need for machine maintenance personnel.	Machine assembly has experienced considerable development over the past decade, and is expected to continue to grow in use.
New materials	Plastic materials offer advantages over steel and cast metal materials in weight savings and, often, fewer processing operations. Parts can be fabricated from metal powder into complex shapes and with fewer machining operations. More widespread use of aluminum and special steels also is anticipated.	Some reduction in semiskilled sheet-metal workers and machine tool operators.	Use of plastics and aluminum will continue to grow.
Numerical control	Automatic operation of machine tools by electronic control devices and coded tape instructions can reduce machining time and labor costs.	Decline in the number of machine tool operators needed, and possibly some increase in machine maintenance personnel.	Numerical control in limited use at present. Applications expected to grow in future, with emphasis on new solid-state programmable controllers and direct computer control.
Improved transfer lines	Transfer line productivity and flexibility have been increased by the introduction of multipurpose machines, interchangeable machine modules, storage banks for parts at intervals in the machine line, and an increase in the number of automatic operations.	Reduction in the number of machine tool operators and inspectors.	Equipment designed to increase transfer machine flexibility is in limited use, and should increase as transfer lines are modified or replaced in the future.

body parts. The computer translates the design into mathematical coordinates that can operate automatic drafting machines and numerically controlled (N/C) machine tools. Engineering, drafting work, and tool production operations can be more closely integrated, thereby speeding up the work flow. Computer use in design may affect labor requirements in the industry in several ways. First, the complex programming required may increase the need for computer programmers. The need for drafters however, should decline. Such computer-aided design is expected to increase in the years ahead.

Engineering research and product development. Using computers, engineers can analyze large quantities of data—sometimes from computer simulation of real situations—to solve design or production problems in remarkably short periods of time. An auto parts manufacturer, for example, saved 9 months to 1 year of development time by using its computer capacities to perform preliminary design calculations on a new long-life piston ring.[2] Computer application to research and development operations is not yet commonplace, but it is a frequently used tool that will probably become commonplace in the future.

Computer control. The application of computers to the control of production operations is a major step in the evolution of computer technology. Computers are being used to keep track of parts and production materials and to forecast potential shortages that could disrupt production. Computer control can aid in attaining uniformity and quality control in machining. It also can aid in work scheduling and production line balancing to increase productivity by directing the proper materials to the worker at his place on the assembly line. Computers can be applied to a group of such operations, tying them together in such a manner as to provide computerized control over an entire manufacturing

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or assembly process. The computer system also can make available large quantities of current data to management to aid decisionmaking. The major auto manufacturing firms are using most of these applications but there are no data on the extent of their use.

Several machine tool manufacturers market computerized control systems for machine operations. One system links a small computer directly (no tapes are used) to four machine tool controllers. The system requires only one operator to load stock and oversee the operation of the system, and it can perform the work of ten conventional machines and operations.[3] Another system uses a small multipurpose computer, memory drum, and a teletypewriter input/output unit to operate simultaneously a combination (up to 16 units) of N/C machines, special purpose machines, and transfer machines. One operator can control the entire system.[4]

Numerical control

Numerical control is a process of operating machine tools through a series of electronic control devices and coded tape instructions. It is a process that is particularly suitable for the manufacture of metal parts in small volume because it eliminates the many expensive fixtures, jigs, and templates otherwise necessary. As such, numerical control techniques are in limited, but increasing, use for the fabrication of the tools and dies needed to operate the industry's many high-volume production machines. Extensive use is being made of numerical control in fabricating sheet-metal parts—a development which ranks among the major applications of numerical control techniques in the United States.

Increased use of numerical control techniques should, as has occurred in other industries, reduce the need for machine tool operators.

Applications of numerical control and direct computer control (discussed elsewhere in this chapter) can be expected to grow. This is one of several methods the auto industry can use to improve the flexibility and utilization of its basic production machines.

Transfer lines

Transfer lines—highly mechanized production lines—are becoming more flexible. Traditionally, transfer lines have been custom built to do one job. Any significant change in the job to be done has generally necessitated a significant change in the construction of the transfer line itself—an expensive and time-consuming process.

Flexibility is being increased by the use of "building block", or "modular", transfer lines, constructed from machinery and equipment consisting of interchangeable, standardized units. These lines can accommodate changes in parts design or retooling for new car models with delays and retooling costs minimized.

The inclusion of storage banks for parts at intervals along a transfer line provides a further increase in flexibility. These storage banks allow a line to continue in operation even if a station in the line stops. Although not a new concept, the use of storage banks has yet to be fully implemented. Computer simulation is being used by at least one manufacturer to predict optimum locations and sizes for storage banks within the transfer lines. The number of automatic operations performed on transfer lines also is increasing, especially time-consuming gaging and inspection operations, which allows a reduction in labor requirements and an improvement in quality control. The new transfer lines are mechanically more complex, requiring more highly skilled maintenance crews.

The development of solid-state programmable machine controllers also contributes to transfer line flexibility. These controllers operate faster and more reliably than the older magnetic-relay controllers they are replacing. It is their programmability that makes them important. Changing the application of a conventional magnetic-relay controller involves changing the physical wiring in the controller, and each such change can take an hour or more to make. The programmable controller needs only to be reprogrammed, which can be accomplished in minutes, rather than hours. Furthermore, it is possible that the use of programmable controllers will lead to more widespread use of computer control.

Machine assembly

Machine assembly (where it can be used) reduces the high labor content of assembly operations, which may in turn lower manufacturing costs. In addition, stricter safety standards and increased emphasis on product performance and quality can often be better met by machine assembly than by manual methods.

The potential impact of automatic assembly operations on labor requirements is considerable because assembly operations are the most labor intensive in the manufacture of autos. There are many simple, repetitive, and monotonous assembly operations that are candidates for machine assembly. Similarly, machine assembly can be applied to some operations that are physically difficult and fatiguing. Job skills for assemblers tend to shift toward machine monitoring and materials handling. The demand and skill requirements for machine maintenance personnel could increase considerably; these can be met by retraining machinists who might otherwise be displaced by the new process.

The diversity and productivity potential of automatic assembly machines are illustrated by the following example obtained by BLS staff during plant visits: One manufacturer uses both an automatic and a manual line to assemble and test torque converters used in automatic transmissions. When the automatic line is in full operation, a crew of 8 people per shift is expected to produce as much as is presently done by a crew of 13 people on the manual line. One

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part of the automatic line already in operation inserts blades into slots in the body of the torque converter—a process in which two people per shift (one attendant and one parts loader) on the automatic line can do as much work as four people per shift inserting blades by hand.

Several major automakers utilize industrial robots to perform many of the welding operations required on a passenger car body, including those that are the most difficult for employees to accomplish. The robots are programmed to make a particular type of weld on a specific body style. The first robot in the line is supplied computer data on the sequence of body styles forthcoming on the assembly line. The first robot also contains a master program for controlling the succeeding robots on the welding line. Each robot reportedly can do work equal to 1¼ welders, thereby reducing the number of welders needed. This is, however, somewhat counterbalanced by the need for a larger and more highly trained maintenance crew. Although there may be little or no labor savings, the quality of the weld is more consistent than is possible with manual welding.

New materials and processes

The use of plastic materials has grown considerably as improvements in both the plastic materials and the plastic-working technology have become available. Advantages of plastics over steel (in those cases where plastics meet rigidity and strength requirements) include lower weight and generally lower tooling costs. Increased use of plastics may reduce labor requirements because plastic parts often require fewer finishing operations than comparable metal parts and large, one-piece molded plastic panels (such as dash panels or front-end body panels) can often replace an assemblage of sheet-metal parts, reducing assembly time. Plastics (especially fiber-reinforced composites using glass or other filaments) are expected to grow considerably in use because of the increased emphasis on lowering vehicle weight to improve fuel economy. Aluminum and special steels also will be used more widely for a growing number of auto components to reduce weight.

The fabrication of metal parts from metal powder is more widely used in the automotive field than in any other industry, and may become even more important due to recent improvements in materials and manufacturing processes. Powder metallurgy parts can be made in complex shapes, of high strength, and to such close tolerances that many secondary machining operations and inspection procedures can be reduced or eliminated, thereby reducing labor requirements.

Output and Productivity Outlook

Output

Industry output increased at an average annual rate of 4.8 percent between 1960 and 1975. The growth rate was higher during 1960-67 period—averaging 7.9 percent a year—than it was during the more recent 1967-75 period, when it averaged 3.2 percent a year. The lower growth rate of recent years reflects several negative economic factors: There was a moderate recession and a major industry strike in 1970, followed—from late 1973 to 1975—by an oil embargo, a period of high inflation, and a severe recession. What tends to be obscured in this growth rate figure is that output rose to record levels in 1971, 1972, and 1973. Auto sales began to rise in late 1975. and continued strong during 1976.

Historically, "regular" size passenger cars have been the mainstay of U.S. auto manufacturers. During the late 1960's, however, smaller passenger cars—intermediates, compacts, and subcompacts, both domestic and foreign—became more important in the marketplace at the expense of regular size and large cars. According to *Ward's Automotive Yearbook*, intermediate and small cars accounted for almost 40 percent of new car registrations in 1966. By 1975 this figure had grown to 77 percent.

The trend toward smaller cars will continue in response to the present Federal Government regulations for fuel economy (27.5 miles per gallon by 1985) set in the Energy Policy and Conservation Act of 1975. To meet such a fuel economy goal with current automotive technology will require a rather large shift to small cars. The popularity of such a shift among car buyers remains to be seen. During the energy crisis from late 1973 to early 1974 the demand for small, fuel-efficient cars was strong. But as fears of gasoline shortages declined, so did some of the enthusiasm for the smallest cars. The strongest sales for 1975-76, according to industry sources, were of the intermediate and larger autos, although sales of the smaller cars did not decline. As of late 1976, however, some dealers were offering discounts on some subcompact models in an effort to improve their sales.

The most likely market structure over the next 5 to 10 years will be a general reduction in size in all categories. Passenger cars presently considered to be of "intermediate" size may well become the standard size. A demand for "full size" cars is expected to continue if production of such cars remains possible under the fuel economy regulations. Several domestic manufacturers have expressed concern that the various Federal regulations on fuel economy, exhaust pollution, and safety standards could affect the size, performance, and general desirability of future passenger cars.

Demand for light trucks and vans (less than 14,000 pounds gross vehicle weight) has been strong since the late 1960's as recreational vehicles gained in popularity. During 1973, demand for heavy trucks (which had increased steadily after a 1970 slump) also grew sharply. Truck production peaked at a record level in 1973, then dropped slightly, but surged to a new record in the 1976 model year. Truck trailer production dropped sharply in 1975, in part because of heavy purchases in late 1974 as customers sought to avoid purchasing 1975 units that were required by law to have expensive anti-skid braking equipment.

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Productivity

Output per employee-hour increased at an average annual rate of 3.2 percent from 1960 to 1975. The increase averaged 3.6 percent annually during 1960-67, slightly higher than the 3.2-percent productivity growth rate achieved during 1967-75.

Growth in output per employee-hour was particularly strong in 1971 and 1972 as output rose sharply from 1970 in response to a very strong demand for new cars and trucks. Productivity continued to grow in 1973 as manufacturers reported a third year of record new car and truck sales; however, by the fourth quarter of 1973, retail sales had begun to fall, causing a final-quarter decline in both output and productivity levels. The decline in productivity continued through 1974, during which there was a sharp drop in output and in employee hours, but a considerably smaller drop in the number of people employed. Apparently the manufacturers chose to cut working hours (especially overtime) and keep their work force intact.

The year 1975 was unusual for the industry in terms of output and productivity. Output continued to decline (for the second year in a row) due in part to the recession and in part to higher auto prices. Although output declined, productivity increased substantially. In this instance, both employee hours and total employment declined at about the same rate—and both dropped considerably more than did output. Thus, the productivity increase resulted, for the year as a whole, from a large drop in the industry's work force and a much smaller drop in output. In fact, output actually increased in two quarters during the year, while employee hours remained at low levels during all four quarters.

Investment

Capital expenditures

Expenditures for new plant and equipment, in current dollars, increased from $790 million in 1960 to $2.1 billion in 1975, an average of 7.4 percent per year. An estimated $2.4 billion was spent in 1976. Since current-dollar figures do not take into account price increases over the years, real capital outlays were less than these figures indicate. The rate of increase in capital expenditures was significantly higher between 1960 and 1967, when the industry was expanding its productive capacity, than during the more recent 1967-75 period. The average annual rates of growth were 16.0 percent in 1960-67 and 6.9 percent in 1967-75.

As shown in table 6, the rate of increase in capital expenditures per production worker was also greater during the first half of the 1960-75 period. Plant and equipment expenditures per production worker in 1974 reached a peak of $4,266, or triple the 1960 total of approximately $1,400 per production worker, and then declined to $3,460 per production worker in 1975.

Capital spending is expected to increase strongly over the next several years. A recent McGraw-Hill survey of capital spending plans[5] indicates that planned expenditures for 1977 will jump to $4.15 billion, followed by an increase to $4.36 billion in 1978. One manufacturer plans to invest $15 billion by 1980 for new, redesigned, smaller passenger cars, while another manufacturer plans to spend almost $2 billion (worldwide) in 1977, and over $2 billion a year in 1978, 1979, and 1980.[6]

This high level of capital spending is necessary to design and produce car models that will meet Federal Government standards for safety requirements, exhaust pollution levels, and—most especially—fuel economy. While funds will be invested in all of the production phases, the emphasis will be on new tooling for updated car models.

The increasing importance of capital relative to labor is reflected in a decline in the ratio of payroll to value added, from 0.451 in 1960 to 0.419 in 1972, an annual average rate of decline of 0.1 percent. (See table 6.)

Funds for research and development

Expenditures for research and development (R&D) in the industry group of motor vehicles and other transportation equipment except aircraft[7] increased from $884 million in 1960 to a planned level of $2.4 billion in 1974, or at an average rate of 7.2 percent a year. Company R&D expenditures were 2.3 percent of net sales in 1960, increasing to a planned level of 2.8 percent in 1974. R&D expenditures are expected to rise to $3.1 billion by 1977.[8]

Research is underway to develop new automobile power plants that meet exhaust emission standards and provide improved fuel economy. Alternative types of power plants being considered range from modified conventional piston engines to alternative engine concepts including the rotary engine, diesel engine, and turbine, stirling cycle, and electric engines. The approach found most feasible by most major

Table 6. Indicators of change in the motor vehicle and equipment industry, 1960-75

Indicator	Average annual rate of change[1]		
	1960-75	1960-67	1967-75
Capital expenditures per production worker	5.9	11.8	7.4
Payroll per unit of value added	[2]–0.1	–0.5	[2]–0.5
Research and development expenditures[3]	[4]7.2	6.8	[4]9.1

[1] Linear least squares trends method.
[2] Final year = 1972.
[3] Data are for motor vehicles and all other transportation equipment except aircraft, and are based on expenditures of manufacturing companies in the transportation industry (except aircraft companies) that have research and development programs. 1974 figures are based on corporate spending plans as reported by McGraw-Hill.
[4] Final year = 1974.

SOURCE: Bureau of Labor Statistics, Bureau of Economic Analysis, Bureau of the Census, National Science Foundation, and McGraw-Hill.

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automobile manufacturers starting with 1975 models is modification of the piston engine through application of catalytic converters—a device attached to the exhaust system which uses platinum and palladium as catalytic agents to convert noxious auto exhaust emissions into water vapor and carbon dioxide. The "stratified charge" engine, a conventional piston engine with an unconventional cylinder head, reportedly has the capability to meet most of the strict emission standards to be implemented after 1978 and may, according to some experts, become more widely used in the early 1980's.

While some improvements in fuel economy may result from refinements in engine design, reducing automobile weight is probably the best way to improve fuel economy. Building smaller cars and substituting lightweight materials (such as aluminum and plastic) are two of the more obvious ways to reduce weight. One manufacturer has already introduced some new car models that are smaller and lighter than the corresponding models of previous years—and this trend will continue.

Employment and Occupational Trends

Employment

Employment in this industry rose from 724,100 in 1960 to a peak of 955,300 in 1973 and then dropped sharply as economic conditions turned downward and auto sales fell, to 774,100 in 1975. This pattern represents an average growth rate of only 1.6 percent a year between 1960 and 1975. During the first half of this period, 1960 to 1967, employment grew at an average annual rate of 3.6 percent. Between 1967 and 1975, however, employment declined by an average of 0.2 percent a year. As sales and production rose again in 1976, employment increased to 850,600.

The long-term trend, however, is for a decline in employment. The BLS projections for 1973-85, indicate a particularly sharp decline from 1973, when employment was at an all-time high.

Employment in the motor vehicle and equipment industry is concentrated in two industry sectors: Motor vehicles (SIC 3711), and parts and accessories (SIC 3714). The motor vehicles sector employed 41 percent of the industry's work force in 1960 and 42 percent in 1975. Employment in the parts and accessories component of the industry accounted for 43 percent of the work force in 1960 and 45 percent in 1975.

The ratio of production workers to total employment has remained fairly stable; production workers accounted for 78 percent of total employment in 1960 and 77 percent in 1975. The rate of employment growth for production workers during 1960-75 was 2 percent—about the same as the all-employee growth rate indicated earlier. The rates of growth in employment of production workers during the shorter term 1960-67 and 1967-75 periods closely parallel trends for total employment.

Occupations

Technological and other changes are expected to alter the occupational structure of the motor vehicle industry by 1985. Employment is expected to increase in only three of the eight major occupational groups—managers, officials, and proprietors; sales workers; and operatives. In the other major occupational groups employment is expected to decline.
ment is expected to decline.

Increased use of computers in design, engineering, and production applications should bring about several changes among professional and technical workers and clerical workers. The number of computer specialists (primarily systems analysts and programmers) is expected to increase by 8 percent. Greater use of computer terminals should increase the productivity of drafting technicians and engineers, although the effect of this on employment is unclear. If the volume of work were to remain unchanged, employment might decline. But there is a strong possibility that computer techniques will be used more intensively to improve vehicle design and weight optimization—new analytical work which could absorb people who might otherwise not be needed. An increase of 34 percent is expected for computer peripheral equipment operators. Keypunch operators are expected to decline by 58 percent as punchcard data entry is supplanted by more sophisticated forms of data entry.

Operatives (semiskilled workers) will continue to be the largest occupational category in the motor vehicle industry, making up about 50 percent of the work force. Many of these workers are engaged in production operations that are relatively labor intensive and have potential for further automation. Semiskilled metal workers (drill press operators, lathe operators, welders, etc.) are expected to decline by 20 percent in response to more widespread use of numerically controlled machines, industrial robots for welding and inspection operations, and more automatic transfer lines.

Although some advances are anticipated in automatic (or machine) assembly operations, the job category of assemblers is expected to grow by 34 percent to employ almost 168,000 people by 1985—by far the largest single occupation in the industry. The general increase in automated production and inspection operations should serve to limit any increase in the number of inspectors needed. Training for many of the semiskilled jobs is relatively brief, consisting primarily of on-the-job instruction for periods of several days to several weeks. Hence, shifting semiskilled workers from one position to another generally should not cause great dislocations.

The impact of advanced production machines on occupational skills was discussed with officials from several auto

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manufacturers visited by BLS staff. In general, a shift toward skilled workers is expected—especially in computer-related occupations—with a decline in unskilled workers and semiskilled machine operators. Maintenance workers would be the occupation most greatly affected, with demand for these workers rising in step with increases in the use of N/C machines, industrial robots, and other automated machines. Skilled machinists who are displaced by automated machines can be retrained to maintain the new equipment.

Adjustment of workers to technological change

The impact of technology on jobs is probably not as critical in the auto industry as it is in many other industries. A substantial proportion of blue-collar jobs are in semiskilled occupations, and operators displaced from one job can be retrained for other jobs more easily than in industries with high skill level requirements. Also, there are areas in auto production (such as final assembly) that are fairly labor intensive, and will continue to be so in the foreseeable future.

Approximately two-thirds of the industry's employees are covered by collective bargaining contracts. All of the contracts contain general provisions pertaining to seniority, layoffs, grievances, retirement, and supplementary unemployment benefits that could be applied to job losses resulting from technological change. Additionally, contracts with two manufacturers contain specific statements concerning technological change. In both cases, the contracts have provisions that require advance notice to the union of planned technological changes, create training programs for qualified employees within the bargaining unit, and allow problems not otherwise resolved to be submitted through the regular grievance procedures.

The recession of 1974 and 1975 caused considerable turmoil in the auto industry. Employment dropped substantially and some plants were shut down sufficiently long for a number of laid-off employees to exhaust their unemployment benefits. By the time new labor contracts were due to be negotiated in late 1976, production and employment had returned to healthy levels—but the recession probably left its imprint on the contract negotiations. In a 4-week strike at one manufacturer, the United Auto Workers won a shorter work year. Employees will receive a total of 13 additional days off over the 3-year contract period, which will serve to create new jobs over the short run and preserve job security in the future. The other manufacturers have since agreed to this pattern.

[1] These data exclude employees in a number of industries which produce components for the motor vehicle industry. According to estimates of the Motor Vehicle Manufacturers Association, more than 517,000 workers are engaged in producing motor vehicle components and thus are classified in industries other than SIC 371, motor vehicles and equipment.

[2] "Computer Speeds Design Production of Piston Rings," *Automotive Industries*, November 15, 1968, pp. 79-85.

[3] "N/C and C/C, New Keys to Productivity," *Automotive Industries*, October 15, 1972, pp. 33-36.

[4] "Computer Controlled Machining," *Automotive Industries*, July 15, 1970, pp. 51-52.

[5] *Preliminary Plans for Capital Spending in 1977-78*, McGraw-Hill Fall Survey, Fall 1976.

[6] "Capital Spending to Set Record in '77," *Automotive Industries*, October 1, 1976, pp. 14-15.

[7] Motor vehicles and other transportation equipment except aircraft consists of SIC's 371, 373, 374, 375, and 379. Separate data for the motor vehicle industry, SIC 371, were not available until 1972. The importance of motor vehicles within this industry group is illustrated by the fact that the motor vehicle segment accounted for over 98 percent of the industry group's R&D funds in 1972 and 1973.

[8] R&D expenditures for 1960, National Science Foundation; planned R&D expenditures for 1974 and 1977, McGraw-Hill.

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Technology and Labor in Petroleum Refining

Rose N. Zeisel and Micheal D. Dymmel

Summary

Technological changes in the refining industry are being made in response to shifts in crude oil supply, changing demand for petroleum products, and environmental and energy considerations, in addition to the usual incentives of greater productivity and lower costs. These changes are primarily in the areas of cracking, hydrotreating, and reforming, in association with advanced instrumentation and computer control. The outlook is for greater emphasis on processes for desulfurization and octane improvement. Because the industry is capital intensive, the short-run effects on labor are likely to be minimal, but in the longer run they will alter job content and may reduce employment growth.

Productivity rose sharply from 1960 to 1977, at an average rate of 4.3 percent annually compared with 2.6 percent in all manufacturing. From 1967 to 1977, the rate was 3.0 percent. The outlook to 1985 is for productivity to rise but at a slower rate than in the last decade. Many uncertain variables affect the outlook including crude imports, gas supplies, and government environmental and energy policies. But for the most part, the industry's productivity in the next decade will depend on the Nation's economic growth and consequent energy needs. Changes in government policies or in the international situation are not dealt with in this chapter.

Capital investments have been increasing almost steadily since the 1960's. By January 1977, operable capacity had risen 50 percent over the decade and 20 percent since January 1973, reversing concerns about capacity shortages. Due to uncertainties of supply and demand and rapidly rising costs, however, there is no general agreement on future capital outlays for capacity expansion. But large investments are anticipated to accommodate changing demand for the industry's products and government environmental and energy policies.

About 160,000 people were employed in the industry in 1977, the largest number since 1962. Following a sharp decline in the first half of the 1960's reflecting very rapid productivity growth, employment was relatively stable until 1973. Since 1973, however, employment has been moving up as technology changes require more unit labor and as the number of very small refineries increases. The outlook to 1985 is for a resumption of the decline.

Technology in the 1970's

Petroleum refining is a series of processes of physical separations and chemical reactions. It involves three major groups of processes: Separation, conversion, and treating. First the hydrocarbon compounds in the crude oils are separated through heating and distillation to recover the lighter products such as gasoline, kerosene, and distillate fuels. Some compounds heavier than gasoline may be "cracked" or chemically converted into higher quality products. Desired products may also be built up by chemical reactions such as alkylation. Others are chemically rearranged, by catalytic reforming, for example. In addition, at some stage of manufacture the products may be treated to remove impurities such as sulfur or metals.

In the past, the objective of U. S. refineries was to maximize gasoline production rather than the output of heavier fuels. Consistent with this objective, they were geared, primarily, to producing high-octane gasoline from low sulfur (sweet) crude petroleum. Moreover, in general, there were no restrictions on levels of sulfur and other impurities in petroleum products.

However, the picture is changing. First, there appears to be a long-term shift in emphasis from gasoline to heavy fuels based on a projected slowdown in gasoline demand and an increase in the market for heavy fuels as a result of the natural gas shortage. Second, environmental protection regulations encourage or require low-sulfur, low-lead products, as well as the reduction of noxious wastes from the refining process itself. At the same time, however, the availability of low-sulfur varieties is declining. As a result of these conditions, refineries must make adjustments to accommodate product changes.

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In addition, changes are taking place in the structure of the industry. Although a number of small refineries are being built, in general, process units are becoming larger, and functions are being consolidated to increase productivity. Average capacity has increased very sharply to over 60,000 barrels per day (as of January 1977), and the labor implications (discussed in the employment section) are significant. Capacity varies considerably among refineries, however, ranging from 500 to 640,000 barrels per day. In general, the smaller plants consist of a crude oil distillation unit plus the necessary auxiliary units, while the larger refineries are considerably more complex. They include, in addition to distillation facilities, cracking, reforming, coking, hydrogen-treating, alkylation, fuel desulfurization, and other processing units. Key advances in the basic refining processes in the last decade, their labor impact, and their rate of difusion are presented in table 4 and discussed in greater detail below.

Computer control

High-speed digital computers improve production efficiency and raise quality through more precise control of the production process. Other benefits also are often cited, such as better technical and operating data and improved plant safety.

Table 4. Major technology changes in petroleum refining

Technology	Description	Labor implications	Diffusion
Computer control	High-speed digital computers, in association with highly complex instrumentation, monitor and/or control various refinery processes; they are used in testing and research laboratories and for management information. Use minimizes costs and improves product quality.	Affects operator's duties primarily, assuming earlier installation of sophisticated instrumentation; requires computer-related technicians.	Installation in one-fourth of refineries constituting more than two-thirds of industry crude capacity.
Improved cracking	Improved riser-cracking techniques use catalysts with more tolerance to feedstocks of higher metal content to provide greater yields of desired products and higher octane ratings. Improved hydrocracking provides more feedstock flexibility.	Increased labor productivity; direct effects are minimal.	Riser method constitutes approximately 40 percent of U.S. cracking capacity. Hydrocracking capacity is equal to 16 percent of the total. Diffusion is expected to be relatively slow.
Desulfurization advances	High-activity catalysts and other advances efficiently reduce sulfur content. Hydrogen-based processes enable refineries to process sour crude, to make low-sulfar feedstocks for modern catalytic reforming units, to produce residuals and distillates to environmental specifications, and to meet pollutant emission controls.	Additional processing increases unit labor requirements for technicians and maintenance personnel.	Process units being built into new refineries. Diffusion will depend on environmental protection requirements and type of crude available. Hydroprocessing capacity increased 30 percent between 1975 and 1978, and is expected to increase another 5 percent by 1980.
Octane-improving processes	Catalytic reforming, alkylation, and isomerization increase gasoline octane ratings without lead additives. New bimetallic catalysts are improving all reforming methods. Continuous reforming eliminates periodic shutdowns for catalyst regeneration.	Direct labor effects depend on refinery complexity. Small plants may need additional operators and maintenance workers. In all cases, productivity would be adversely affected.	By 1978, reforming accounted for 22 percent of crude capacity; isomerization, 2 percent; alkylation, 5 percent. Low-lead requirements suggest increased importance of octane-improving processes.
Energy conservation methods	Increased use of heat exchangers, furnace air preheaters, thermal insulation, gas and hydraulic turbines, waste-heat steam generation, process improvements.	Increases maintenance labor, particularly in older refineries; also increases demand for engineering skills.	By early 1976, energy use was cut 10 percent below 1972. Expectations are for an additional 15-percent cut by 1985.
Preventive maintenance technologies	Use of ultrasonic testing, X-ray testing, infrared cameras, magnetic particle testing, and corrosion probes to determine equipment reliability.	Newer sophisticated preventive maintenance equipment requires highly trained personnel, but may require fewer unit employee hours as downtime is reduced. Maintenance craft consolidation also reduces unit labor requirements.	New testing methods are widely used; use depends on complexity and age of equipment.

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In process control, digital computers are applied to various refining processes ranging from crude distillation to on-line gasoline blending. Open-loop control is most common: data received from plantwide on-stream sensors are monitored and the operator is notified when machine changes are required. However, closed-loop control is increasing in use in the newest installations. The trend is toward use of mini- or microcomputers which, while linked to a central control center, control separate functions. Required adjustments in the production process are made automatically, thus eliminating some of the operator's functions.

Digital computer use is generally more common in large complex plants. Approximately one-fourth of American refineries use digital computers in various applications,[1] but these plants constitute more than two-thirds of total U.S. capacity.[2] With current trends towards the construction of larger, more complex plants, it is expected that practically all future refineries will incorporate one or more process control digital computer systems.

The use of very sophisticated instrumentation generally precedes or accompanies computer installation, and so the labor implications of the computer cannot be easily sorted out. In a refinery visited by the BLS staff, the computer monitored information from more than 1,000 electronic instruments, such as chromatographs, mass spectrometers, and octane analyzers, that are located at the process unit and continuously measure product quality. Their importance lies in the speed with which problems can be corrected, and also in their tie-in to computer control. All U.S. refineries use analyzers, but the number and sophistication of the instruments vary with the size and complexity of the plant.

The effect on employment is associated largely with the degree of sophistication of the refinery's instrumentation. For example, fewer analyzer repairers, operators, and lab technicians may be required where on-line monitoring is possible.[3] In a modern plant, one technician may take the place of three or four technicians or operators in an older plant which still maintains sample testing and manual recording. On the other hand, jobs such as programmers and systems analysts increase with the installation of computers. A BLS study[4] shows, however, that the number of some computer-related jobs in a plant may decrease after the initial phases of installation and programming are completed.

[1] *International Petroleum Encyclopedia*, 1977, pp. 443–44.

[2] Ibid., pp. 316–20.

[3] "Process Computers—They Do Pay Off in Refineries," *Oil and Gas Journal*, Dec. 3, 1973, p. 62.

[4] *Computer Manpower Outlook*, Bulletin 1826 (Bureau of Labor Statistics, 1974), pp. 36–37.

With the installation of computer process control, changes are necessary in the operator's duties. One example is clearly shown in a BLS survey of employment implications of computer process control.[5] The duties of an operator of a fluid catalytic cracking unit before computer control were to manually adjust automatic analog controllers at the control console and to monitor automatic data logging equipment. After installation, the computer controls and monitors a large part of the process and automatically logs the data, although the operator still performs manual control. In case of emergency, the operator can take control of any part or all of the process.

Improved cracking

Fluid catalytic cracking is a refining process that converts heavier oils into lighter, more valuable products such as gasoline, primarily by chemical reaction in the presence of a catalyst. The technique of riser cracking was developed concurrently with a new generation of highly active catalysts in the early 1960's. Considered more efficient than older techniques, this method presently is in use in over 40 percent of U.S. cracking capacity.

Hydrocracking, an older, but greatly improved method of cracking, has several advantages over the conventional "cat-cracker." These include the capability to meet environmental specifications of low sulfur and nitrogen more efficiently and flexibility to handle variations in crude stock and in products desired. Currently, however, hydrocracking accounts for only about 16 percent of cracking capacity, and the diffusion is expected to be slow, due primarily to the very high investment and energy usage required for this process.

For both types of cracking, continually improved catalysts and regeneration methods enable more efficient processing of oils with high contents of sulfur and metals. To meet new product specifications and increased use of high-sulfur crudes, refineries with older cat-crackers may need to change over to the more efficient processing methods.

In general, the effect on labor utilization of improved cracking procedures in place of older cracking methods is minimal.

Desulfurization advances

Hydroprocessing to reduce impurities, particularly sulfur, will become increasingly important as demand increases for low-sulfur residual and distillate fuels. In addition, stricter environmental protection regulations and greater utilization of high-sulfur crudes due to dwindling supplies of sweet crudes

[5] *Outlook for Computer Process Control: Manpower Implications in Process Industries*, Bulletin 1658 (Bureau of Labor Statistics, 1970), p.29.

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will lead to strong growth in desulfurization capacity.

Desulfurization is an important factor in better enabling refineries to process sour crudes. For this purpose, sulfur removal may follow initial crude distillation. Desulfurization is also performed downstream to meet the stringent requirements of catalytic reformers and to control pollutant emissions from the catalytic cracking process. Residual and heavy gas-oil desulfurization, the smallest but most rapidly growing segment of hydroprocessing capacity in the United States, is performed as the last step in the production of those fuels. New refineries are being designed to produce low-sulfur products from high-sulfur crudes, and existing plants are revamping their process units when changes become necessary.

Various hydrogen-based processes (hydrodesulfurization, hydrorefining, hydrotreating) are used for sulfur removal. All are based on chemical reactions between oil and hydrogen in the presence of a catalyst. Advances involving separate demetallization processes and new high activity catalysts are reducing problems related to metals accumulation and need for frequent catalyst regeneration. However, the costs are still quite high. With some desulfurization processes, off-site regeneration of catalysts by specialized companies is increasing as an economical solution to catalyst-related problems.

The trend is clearly toward an increasing capability of refineries to process sour crudes. Total hydroprocessing capacity increased 30 percent between 1975 and the start of 1978 and is expected to increase an additional 5 percent by 1980. Residual and heavy gas oil desulfurization capacity more than tripled from 1975 to 1978.[6]

Since additional processing is required for desulfurization and demetallization, unit labor requirements for operations and maintenance personnel may increase. These increases may be temporary, however, as the processes become integrated into the overall operation of the refinery.

Octane improvement

Catalytic reforming, a process which improves the octane rating of gasoline or fuels, is particularly important today in view of the Federal Government's requirements for lower lead and lead-free gasoline. To increase yields of high-octane gasoline without lead, low-sulfur feedstock is necessary. The desulfurization of feedstock, discussed in the previous section, is therefore necessary.

New bimetallic catalysts are making all reforming processes more efficient, increasing yields and octane ratings over those possible with conventional catalysts. In addition, the process of continuous reforming eliminates periodic shutdowns because, unlike other reforming methods, it continuously regenerates the catalyst.

To meet the low-lead requirements, refiners increased their reforming capacity by roughly 19 percent between 1972 and 1978. In that period, the use of bimetallic catalysts more than doubled, to over 60 percent of total reforming capacity. At the start of 1978, continuous reforming accounted for 4 percent of total catalytic reforming capacity compared with about 69 percent for semi-regenerative reforming, and almost 27 percent for the older process of cyclic reforming.[7]

In addition to reforming, the processes of alkylation and isomerization provide increased octane ratings in gasoline. Developed in the early 1940's to produce aviation fuels, these processes are not widely used now, representing only about 5 percent and 2 percent, respectively, of crude capacity (compared to 22 percent for reforming). However, they will become increasingly important as leaded gasoline is phased out.

Although the phasedown of leaded gasoline may not be as severe for the large refineries capable of wide process adjustment, it will be particularly difficult for smaller, older refineries, geared primarily to producing leaded gasoline. Some of these smaller refineries may have problems associated with capital acquisition or procurement and construction of the needed equipment. In addition, more operators may be needed in refineries lacking process control systems. More maintenance labor may also be required by the small plant. In all cases, however, productivity would be adversely affected by the additional processes required to increase octane ratings.

Energy conservation

Because of the high costs of new refining technologies, particular emphasis is being placed on reducing costs through energy conservation—the more efficient utilization and generation of fuel and power.[8] Current technologies such as heat exchangers, furnace air preheaters, gas and hydraulic turbines, waste-heat steam generation, and thermal insulation are now being improved. Minor process adjustments, automatic instrumentation, increased maintenance, and intensified surveillance of operations are also important in reducing refinery energy consumption.

The labor implications of energy conservation in the refinery are considerable. Some companies have

[6] "Federals Shape U.S. Refining Industry," *Oil and Gas Journal*, Mar. 20, 1978, pp. 63–66.

[7] Ibid.

[8] *Oil and Gas Journal*, Mar. 29, 1976, p. 74.

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set up energy systems departments whose managers closely control energy use. In addition to managerial and engineering skills, more employee hours of skilled craft and maintenance workers may be required for efficient energy utilization, particularly in the older refineries.

Preventive maintenance

Special emphasis is being placed on preventive maintenance, particularly the use of electronic instruments to locate defects in and measure the deterioration of equipment before problems arise. Through the use of ultrasonics, X-rays, and electrical corrosion probes, wear and corrosion in pipes and vessels can be measured on- or off-stream, sonic testers can detect high-frequency sounds generated by gas leaks from valves and fittings, and magnetic particle tests and infrared cameras can also pinpoint structural defects in some equipment.

Preventive maintenance reduces downtime and maintenance costs, but the effect on labor is difficult to assess. Maintenance labor requirements vary with the complexity and age of the refinery, the sulfur in the crude, and the extent to which maintenance is subcontracted. Newer refineries may have less maintenance because modern materials, e.g., corrosion resistant, are more fully utilized. In general, however, important changes are occurring which are reducing unit labor requirements for maintenance personnel. These are discussed in the section on employment and occupational trends.

Production and Productivity Outlook

Output

The steady growth in petroleum refining output since World War II was interrupted only by small declines in 1949 and 1958 and again in 1974 and 1975. Overall, from 1960 to 1976, output rose at an average rate of 2.9 percent annually.[9] The growth rate, however, was considerably more rapid in the strong economy of 1960-66 (3.2 percent) than in the 1966-67 period (2.4 percent). The latter period included the embargo and the 1974-75 production cutback associated with the economic recession and energy conservation. But in 1976 and 1977, output jumped to peak levels, recording the most rapid annual rates of growth since 1955.

[9] *Productivity Indexes for Selected Industries, 1977 Edition,* Bulletin 1983 (Bureau of Labor Statistics, 1977). Output measure based on Bureau of Mines data.

There is no general agreement on the level of domestic demand for refinery products in 1985.[10] Many observers expect gasoline demand to peak out in the next few years, while demand for distillate and residual fuels is expected to increase as utility and industrial users substitute fuel oil for natural gas.

Imports

Until the early 1960's, the United States was self-sufficient in refined petroleum. Even in the first half of the 1960's, domestic refining capacity could supply more than nine-tenths of domestic demand; product imports consisted almost entirely of residual fuel. But in the 1965–73 period, demand for petroleum products expanded considerably more rapidly than capacity, and by January 1973 operable capacity could supply less than 80 percent of the demand. Thus, the gap between domestic demand and supply had been growing for years when the crude oil embargo and price increases intensified the problem. Product imports rose to peak levels in 1973, averaging 3 million barrels daily.[11] Residual fuel was still the major refined product imported but other imports had also risen substantially.

However, the demand/supply situation reversed itself following the crude oil embargo when concern rose sharply about our self-sufficiency. Capacity increased as plants were expanded and new plants were built, while demand declined after three decades of continuous growth. Consequently, the gap between refining capacity and demand greatly narrowed, and our dependence on imported refined products in 1975 dropped back to roughly that of the mid-1960's. Although demand has been rising, capacity increases continue to hold down the gap filled by product imports. In 1976, imports of refined products averaged 2 million barrels daily, 11 1/2 percent of domestic demand, the lowest proportion since 1967.

But crude distillation capacity alone is not a measure of the industry's capability to provide for domestic demand, even assuming available crude supplies. Residual fuel has been and continues to be our major import because, as discussed earlier, domestic refineries have not been interested in or geared to processing residuals. The problem is now complicated by government regulations which require low-sulfur residuals, sometimes necessitating changes in technology. Nevertheless economic incentives and the outlook for rising demand have re-

[10] See *Projections of Energy Supply and Demand and Their Impacts: Annual Report to Congress. Vol. II, 1977* (U.S. Department of Energy, Energy Information Administration, 1977), ch. 6, pp. 127–53.

[11] Bureau of Mines data.

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sulted in more domestic processing of residual fuel—from 30 percent of domestic demand in 1973 to about 56 percent in 1977. Imports of residual fuel hit a low of 1.2 million barrels a day in 1975 and have not increased greatly since then, in spite of a sizable increase in demand.

The outlook for imports of refined products is not clear.[12] Opinions differ as to domestic capacity growth and shifts in demand, aside from the availability of crude supplies or, in the longer run, the possibility that oil-producing countries will move into refining.

Productivity

Productivity in refining rose sharply in the post-World War II period. From 1960 to 1977, output per employee hour in the refining industry increased at an average rate of 4.3 percent annually, compared with 2.6 percent in all manufacturing.[13]

Productivity growth was considerably more rapid and steadier, however, from 1960 to 1967 (7.1 percent) than from 1967 to 1977 (3.0 percent).

In the last few years of the 1960's, productivity growth leveled off at a relatively low rate. In 1972 and 1973, productivity rose very sharply; this was followed by a sizable decline in 1974. While the recovery since then has been moderate, productivity in 1977 was back to the high level of 1973. These erratic productivity movements were associated with the embargo and the events that followed. There were erratic changes in refining output, discussed above, such as the unusually steep increases in output in 1973, 1976 and 1977, and the decline in 1974, the first since 1958. There were also unusual changes in employee hours.

A roughly similar pattern of change in the industry since 1960 is evident in data on payroll per unit of value added, i.e., labor as a percent of the value of shipments less materials and other costs. As shown in table 5, payroll per unit of value added fell at an average annual rate of 3.2 percent from 1960 to 1975, compared with 1.1 percent for all manufacturing, indicating a relatively greater increase in efficiency. The stronger industry position in the first half of the period 1960–66 is evident in the sharp decline in payroll/value added of almost 6 1/2 percent annually. In contrast, the ratio showed only a minor change of about 1 percent in the 1966–75 period, having registered sizable increases for several years.

[12] *Projections of Energy Supply and Demand*, p. 137.

[13] *Productivity Indexes, 1977 Edition*, pp. 75–76.

Table 5. Indicators of change in petroleum refining, 1960-75

Indicator	Average annual percent change[1]		
	1960-75	1960-66	1966-75
Payroll per unit of value added ..	-3.2	-6.3	-1.0
Capital expenditures per production worker	13.4	9.1	10.7

[1] Linear least squares trends method.
SOURCE: Bureau of the Census.

Productivity differences

Data on productivity differences among establishments in an industry with a high degree of specialization may provide some insight into the factors associated with high productivity performance within the industry. In a study of 1967 Census data,[14] petroleum refineries were ranked by value added per production worker hour to provide a rough indication of the range of productivity differences. In this industry, average value added per production worker hour in the highest quartile was almost 11 times greater than in the lowest quartile.

Wide productivity differences in the refining industry may reflect differences in size, management, complexity (type of processing), labor, capital outlays, etc., but the limited data preclude general conclusions. Nevertheless, the 1967 data suggest that size may be important (table 6). Establishments in the highest quartile had an average employment almost four times greater than those in the lowest quartile. This is verified by studies[15] which show that labor productivity increases with capacity and with employment, up to a point. Small plants must maintain a minimum staff of operators and maintenance and technical personnel to run the refinery; as capacity increases, the number of production workers needed per thousand barrels of output declines sharply. But at some point, the advantages of size may be offset by duplication of process units.

Capital expenditures

Capital expenditures for refining plants increased 11.2 percent annually from 1960 to 1975 to a total of $2.2 billion—more than four and one-half times the outlay in 1960. The increase, however, was not even over those years. In the first half of the 1960's, annual outlays declined or remained relatively constant; from 1965 to 1971 they rose extremely rapidly;

[14] Based on unpublished data prepared by the Bureau of the Census for the National Center for Productivity and Quality of Working Life.

[15] Studies by W.L. Nelson published in the *Oil and Gas Journal*. See "Maintenance Material and Labor", Jan. 13, 1975, pp. 57–59.

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Table 6. Value added and employment in petroleum refining: Ratios of "highest quartile" to "lowest quartile" plants and to average plant, 1967

Measure	Ratio of highest quartile to lowest quartile	Ratio of highest quartile to average
Value added per production worker hour	10.7	1.8
Average employment per establishment	3.7	1.5

NOTE: Establishments were ranked by the ratio of value added per production worker hour.

SOURCE: Based on unpublished Census Bureau data prepared for the National Center for Productivity and Quality of Working Life.

in 1972 and 1973 they declined; and in 1974 and 1975 they jumped very sharply. The average outlay in the 1960–75 period was $917 million.

These data, however, reflect costs unadjusted for changes in prices. Adjusting the dollar figures by the Nelson index of refinery construction costs[16] reveals that real investment barely doubled from 1960 to 1975. From 1966 to 1975, real investment rose one and one-half times compared with three and one-half times for dollar outlays. However, increases in refinery costs were offset by the greater efficiency of plant and equipment. When adjusted for productivity changes by Nelson's "true cost" index, adjusted real capital outlays rose two and one-half times in those 9 years, and almost three and one-half times from 1960.

Petroleum refining is highly and increasingly capital intensive. Labor costs were less than 13 percent of the value of the product in 1975 (compared with 48 percent in all manufacturing), having dropped sharply and steadily from 34 percent in 1960. As capital expenditures rose sharply and the number of production workers declined from 1960 to 1975, capital outlays per production worker rose almost sevenfold. After adjustment for price and productivity increase, real outlays per production worker rose almost fivefold.

These large capital expenditures resulted in additions to daily capacity of 3.2 million barrels, an increase of 24 percent in the 5 years from January 1972 to January 1977. From January 1974 to January 1977, 28 "grass roots" plants were built, accounting for slightly over 20 percent of the total increase in operating capacity in those years.[17] However, almost all of these were very small, of very simple design and limited flexibility. With incentives available to small refineries, 19 of these new plants had less than a 10,000-barrel daily capacity. Only one had a capacity of more than 40,000 barrels.

There is no general agreement on the outlook for capital expenditures for expansion. In addition to judgments on the need for additional capacity, capital outlays for expansion will be influenced by the increasingly heavy costs of new plant and equipment. In general, however, there is agreement on the necessity to modify existing facilities to cope with changing demand and supply conditions. Even in this, there is a wide range of views relating to the future course of gasoline demand and likely developments in coal gasification and liquefaction. In addition, future government environmental and energy policies will affect capital outlay decisions. Of great concern is the increase in environmental protection costs, which averaged 12 percent of the total petroleum industry's outlay in 1975;[18] data for the refining sector alone are not available.

Employment and Occupational Trends

Employment

About 160,300 people were employed in the refining industry in 1977, the largest number since 1962. A decline starting in the late 1940's continued unabated through the mid-1960's, reflecting the very sharp increase in productivity through most of the period. After 1973, however, employment turned up again.

In the first half of the 1960's, the sizable employment decline was associated with a sharp reduction in the number of refineries and a productivity growth rate which was more than double the rate of growth of output. From the mid-1960's to 1973, employment was relatively stable, although it dipped to a low point of 145,000 in 1969. After 1973, however, several years of rising employment brought the level up to that of the early 1960's. This change in the direction of employment reflected, in addition to technology changes which required more unit labor, an increase in the number of very small refineries. Overall, from 1960 to 1977, a relatively moderate annual average employment decline of 0.3 percent was registered.

Refinery employment to 1985 is projected to resume its decline. Based on the economic assumptions stated in the introduction, the BLS projects a decline to 137,000 employees in 1985, or a drop of 1.9 percent annually from 1977 to 1985.

These data reflect the technological, structural, and skill changes which have affected employment in

[16] Nelson Index published in the *Oil and Gas Journal*. See issue of Jan. 26, 1976.

[17] *Trends in Refinery Capacity and Utilization* (Federal Energy Administration), June 1976, pp. 4 and 7, and June 1977, p. 14.

[18] Data from the Bureau of the Census.

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the industry. A modern refinery today with an input of 100,000 barrels per day employs about 300–350 workers on three shifts. An older refinery with that capacity which has been modernized employs about 700 workers; that same plant would have employed almost 1,000 persons in the 1950's.

Occupations

As discussed earlier, technological and structural changes are altering traditional concepts of job content and duties. More importantly, duties are being consolidated, as in the case of maintenance crafts, or partially removed from the refinery, as in the case of contract maintenance.

Maintenance craft consolidation is an important labor development of the last decade which increases the flexibility of the work force while it reduces the number of workers required per processing unit. Under most maintenance consolidation plans, skilled workers who have attained journeyworker status in one craft are trained to handle other crafts (for example, a boilermaker who learns pipefitting), thus eliminating the need for several workers, each with a specific craft duty. Such consolidation is becoming more widespread. Of 104 refineries studied by BLS in 1976, about one-fourth reported craft consolidation plans, double the number reported in 1965.[19] In most plants, consolidation was limited to two designated crafts but in many plants consolidation incorporated all maintenance crafts. These skill combinations fall into a single job classification, "general mechanic." A further development of this practice is the combination of operative and maintenance skills by one worker, who may be known as a "running operator." Two running operators can handle a processing unit of 100,000-barrel capacity, compared to three operators and a maintenance worker required in the average refinery of similar capacity.

The trend to maintenance craft consolidation may in time contribute most importantly to revising job content and standard occupational patterns. By eliminating the lines of craft duties, craft consolidation practices generally establish new single job classifications with new duties and training.

Contract maintenance is performed by workers supplied by outside firms on a contract basis, and permits a refinery to have a relatively small year-round maintenance staff. Although contract workers are generally used for special peak work periods such as during shutdown, they may also be employed year round on regular maintenance. Prior to the practice of contract maintenance, a refinery might have had a ratio of 2 maintenance workers to 1 operator. Now, excluding contract workers, the ratio of maintenance workers to operators in that refinery may be 1 to 2.

The practice of contracting out is reducing employee hour requirements in the refinery, but data are not available on its extent. The importance of this practice is evident in the fact that in this industry 9 of 13 labor-management contracts (covering 1,000 workers or more) studied by the BLS in 1975 contained provisions limiting subcontracting.[20]

Job and skill changes. Job content and skill requirements are being substantially changed by the sophisticated instrumentation, particularly for maintenance and lab technicians. In many cases, decisionmaking is being transferred from the employee to the machine. In the older plants, technicians may take readings of various instruments every 4 hours and may record the information manually. In modern refineries, computer consoles in each process unit record the data from on-line instruments and feed the data into a central computer system. As many as a thousand signals can be received by the computer and checked against limits for problem areas. In blending, for example, several products must go into the finished gasoline in proper proportions. To do this, the operator merely sets the controls for the specified percentages, etc. Samples from the stream are then automatically analyzed; changes can be made by the operator. The computer will continuously monitor the process and report information on demand.

Manual skills, already at minimum levels in the refinery, continue to decline. Even the truckdriver who loads the gasoline for delivery uses an automated system. The driver removes the cover of the tank, puts a punchcard into a slot, and pushes a button. The required quantity of the correct product fills the truck, after which the flow shuts off automatically. When this job is not automated, loaders and pumpers are employed to do the work.

Due to the many changes occurring in the industry, the occupational distribution in 1985 is expected to be significantly different from the 1970 pattern. In the BLS projections of occupational employment, professional and technical workers, more than one-fifth of all refinery workers, are expected to decline moderately from 1970 to 1985 but to retain about the same share of total employment. This is in contrast to the pattern of the 1960's, when professional and technical workers rose very sharply both in number of jobs and as a proportion of total employment. The ma-

[19] *Industry Wage Survey; Petroleum Refining, April 1976*, Bulletin 1948 (Bureau of Labor Statistics, 1977). See also BLS Bulletin 1741, p. 2, for April 1971 data.

[20] *Characteristics of Major Collective Bargaining Agreements, July 1, 1975*, Bulletin 1957 (Bureau of Labor Statistics, 1977), p. 86.

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jor occupations in this group are chemcial engineers, chemical technicians, and computer personnel. Other occupations are chemists and engineers.

Operators constituted almost one-fourth of all refinery workers in 1970, approximately the same proportion of total employment as professional and technical workers. Chief operators, numerically one of the largest groups of workers, are the highest paid production workers in the refinery. BLS projections indicate a decline of about 8 percent in the number of operators from 1970 to 1985 but an increase in their share of the total to over 25 percent. Craft and kindred workers are expected to decrease in number by about 7 percent from 1970 to 1985; however, their share of the total may increase slightly. This group also constitutes more than one-fifth of all workers and includes general mechanics, instrument repairers, machinists, electricians, pipefitters, and welders.

A recent BLS survey[21] of occupations in this industry reaffirms the very large proportion of skilled workers. Skilled maintenance workers constituted one-fifth, and chief and assistant operators one-fourth, of all production workers in 1976.

Laborers constituted a small proportion of employment—only 3 percent in 1970—and are expected to decline further by 1985 as manual handling of materials becomes obsolete.

Adjustment of workers to technological change

Programs to protect employees from the adverse effects of changes in machinery and methods may be incorporated into contracts or they may be informal arrangements between labor and management. In general, such programs are more prevalent and more detailed in industries and companies which negotiate formal labor-management agreements. Contract provisions to assist workers in their adjustment to technological and associated changes may cover new wage rates, new job assignments, retraining, transfer rights, layoff procedures, and advance notice of changes planned by management, including machine changes or plant closings. They may also include various types of income maintenance programs such as supplementary unemployment benefits or severance pay.

In the refining industry, there is a high degree of unionization; approximately 90 percent of the employees are covered by collective bargaining agreements. Contracts usually run 2 years, and negotiations are conducted on a company basis, with the first settlement establishing the pattern for later bargaining. The Oil, Chemical and Atomic Workers Union (OCAW) represents about two-thirds of the workers covered; the other third are covered by several independent unions—the Teamsters, the Operating Engineers, and an affiliate of the Seafarers' Union.

As mentioned earlier, 13 major agreements covering 1,000 workers or more were studied by the BLS in 1975.[22] In these contracts, covering 25,000 workers, employee seniority was generally the determinant in the order of layoff and recall, assuming equal ability. Interplant transfers and preferential hiring opportunities for displaced workers were mentioned in 8 of the 13 agreements, covering 13,200 workers. Four agreements provided relocation allowances for transferred workers.

Training for new skills and changing job content is a continuous process in most refineries. Of the 13 agreements studied by the BLS, 4 had apprenticeship provisions, and 7 provided for on-the-job training. In refineries visited by the BLS staff, training is required for 4 years or more for a senior technician. In one plant, the new worker, generally a high school graduate, receives 4 months of classroom training covering refinery equipment and the math and chemistry needed for the job. The trainee is then assigned to a shift but continues with on-the-job training, spending about 5 months on each of four assignments. After 2 years, the trainees are qualified as refinery technicians. In some refineries, the ladder of promotion may be from technician I to technician IV, with perhaps 1 year or more between grades.

Although seldom cited specifically, technological change is often the major factor in job reclassification provisions. One contract stated, "If during the term of this agreement, a significant change in job content has been effected by the Employer to the extent that a wage rate is considered to have become inappropriate . . . , the union may request in writing a study and analysis of the job involved . . . , any dispute arising in regard to the wage rate of such job shall be the subject of negotiations and shall not be subject to the grievance procedure."

Advance notice to the workers of plans for layoff or plant shutdown or relocation was required in 10 of the 13 contracts studied by the BLS, a considerably larger proportion of contracts and of workers than in all manufacturing in the case of plant shutdown or relocation and somewhat larger in the case of layoff. However, in only one contract was there specific mention of advance notice of plans for technological change.

Changes which can result in a reduction in force, possibly from technological change, were covered in

[21] *Petroleum Refining, April 1976*, BLS Bulletin 1948 table 1

[22] *Major Agreements*, BLS Bulletin 1957, pp. 86,87,89.

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one contract as follows: "The company will give the union 14 days notice when job classifications are to be eliminated or when changes are to be made . . . in a classification." Severance pay provisions were more common in petroleum refining contracts than in most other manufacturing industries. All refinery contracts had provisions for grievance and arbitration, procedures found in almost all major collective bargaining agreements in manufacturing.

Cooperation between workers and management was reaffirmed in the "Memorandum of Agreement" of one of the major contracts which concerned the "job security of employees who may be affected by technological improvements, the construction of new units or the establishment of new processes." This agreement stated that the union "will continue to cooperate in adopting more efficient work practices . . ." and the company "will manage its operations and its work force in such a way that layoff . . . will not occur." When the company decides layoffs are unavoidable, 60-day written notice is required. If, after discussion, labor and management are unable to resolve the problems," . . . then either party may at any time terminate the basic agreement upon 60 days written notice."

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Technology and Labor in Printing and Publishing

Robert V. Critchlow

Summary

New technology is being introduced throughout the printing and publishing industry. These innovations frequently involve the application of electronic techniques in place of mechanical equipment. High-speed phototypsetting machines, computerized typesetting, video display terminals, and electronic scanners are among technologies which have brought about significant changes in composition and typesetting—areas where about 2 out of every 5 printing craft workers are employed. Employment in printing craft occupations associated with letterpress or hot-metal typesetting has been declining as offset printing, which involves photographic techniques, has become increasingly dominant. Technological changes also are reducing labor requirements and modifying job skills in platemaking and printing press, binding, and mailroom operations. Employment in computer-related occupations has been increasing. Training programs have been a major mechanism for providing employees with skills associated with new technology, including photographic typesetting techniques, typing skills to prepare tapes used to operate equipment, and techniques of electronic maintenance.

Output (as measured by the Federal Reserve Board index) grew fairly steadily during 1960-81, increasing at an annual rate of 3.4 percent. The rate of increase averaged 5.4 percent from 1960-67 and 2.6 percent from 1967-80. Output expansion has been slower in newspapers than in other sectors of the industry. Capital expenditures grew rapidly from 1960 to 1967, but declined thereafter.

The industry employed about 1.3 million people in 1981. Employment has grown relatively slowly, increasing at an average annual rate of 1.5 percent between 1960 and 1981. Growth is projected to range between 1.0 to 1.9 percent between 1981 and 1990. Newspapers and commercial printers are major employers, each providing jobs for about one-third of the industry's work force. Within the major broad occupational groups, employment is projected to increase for professional and technical workers; managers, officials, and proprietors; sales workers; and clerical workers. Employment is also expected to increase slightly for craft workers as a group, although a decline is projected for typesetters, one of the largest occupations in the industry. Employment declines are projected for operatives, service workers, and laborers.

Technology in the 1980's

Technological changes are taking place in all sectors of the printing and publishing industry (SIC 27). The pace of change has been particularly rapid in composition and typesetting. Several technological developments—including the use of computers for typesetting, video display terminals (VDT's), optical character recognition scanners, and phototypesetting machines—have been brought together to form electronic composition systems with tremendous capacity. Electronic composition, in some applications, is having a strong impact on skill requirements and employment for typesetters (who make up about 40 percent of all printing industry craft workers), editors, reporters, and other professionals, and clerical workers. A major effect of electronic composition is to shift much of the composition and keyboarding of copy away from the composing room, where the employment of typesetting craft workers is projected by BLS to decline by 25 percent between 1978 and 1990. Instead, in the front offices of newspapers, periodical publishers, and other firms, reporters, staff writers, editors, and others use video terminals in place of typewriters to enter the material into a computer system that will photocompose with a minimum of additional work. Employment in these areas could increase.

Technology is advancing in many other areas in addition to electronic composition. Electronic (or optical) scanners are being applied to colorprinting, where they eliminate much of the time-consuming handwork previously involved in the manual color separation process. Data transmission (the electronic transmission of words, photos, etc.) has grown more sophisticated and can be combined with automatic scanning and platemaking equipment for rapid, highly automated transmission of typeset material to printing plants at several locations. Web-offset printing is being used by virtually all weekly and smaller daily newspapers and a growing number of large daily newspapers and is becoming more

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widely used in book, periodical, and commercial printing. This has increased the demand for lithographic craft workers and decreased employment in some letterpress-related occupations, especially those involved in printing plate preparation. Improvements in binding and newspaper mailroom technology have reduced labor requirements in material handling and assembly tasks. Some printing workers displaced by new technology are being reassigned and retrained—those in unionized plants according to provisions of labor agreements relating to protection of printing workers from the adverse impact of new technology. A description

Table 1. Major technology changes in printing and publishing

Technology	Description	Labor implications	Diffusion
Electronic composition	Typesetting computers perform some typesetting tasks automatically; these include setting margins and hyphenating words. Video display terminals combine video screens, typewriter-style keyboards, and linkage to typesetting computers, allowing greater control over entering, correcting, and editing copy prior to the actual typesetting operation. Phototypesetting machines set type on film or photosensitive paper rather than in metal. They operate at high speeds, and many models offer great flexibility in selecting and changing type styles and type sizes.	Electronic composition equipment, under certain conditions, can shift almost all composition and keyboarding operations to professional and clerical employees (such as editors, reporters, staff writers, typists, etc.), often bypassing the typesetting employees who traditionally have done this work. Professional and clerical workers must be able to type, and must learn to use video terminals and data processing procedures. Some increase in the number of computer specialists and editors is expected. Electronic composition has caused a decline in the employment of typesetting craft workers. This is partly due to the shift in typesetting operations to professional and clerical workers, and partly due to the greater productivity of the newer equipment. Employment of typesetters probably will continue to decline during the 1980's. The introduction of typewriter-style keyboards has required retraining for these craft workers, and has made it possible for most people with average typing skills to learn to set type. Some typesetting craft workers have been retrained to monitor high-speed automatic typesetting machines, and to handle other tasks related to phototypesetting. Other craft workers are being retrained in different fields, are retiring early, or are taking jobs in printing firms that do not yet use electronic composition processes.	Computerized typesetting is used throughout the printing industry. Newspapers are among the most intensive users; nearly 2,000 systems were in operation in 1978. Applications of typesetting computers are expected to grow, especially with the development of microprocessor technology which will reduce size and cost of equipment and make it more accessible to smaller offices and printing firms. Typewriter-style keyboards now dominate the industry. Video terminals (with typewriter keyboards) are well established and growing rapidly.
Optical character recognition scanners for typesetting	These devices sense typewritten material placed beneath their scanning heads and convert the information into digital signals for later use in various parts of the printing process.	When scanners are applied to typesetting operations, someone—whether clerical, professional, or craft worker—has to do the initial typing. After the typed material has been scanned and recorded, it becomes part of a computerized, automatic typesetting system that can frequently bypass the conventional typesetting process of keyboarding the material, and also bypass the associated craft workers.	Scanners perform a limited amount of typesetting work. Use could increase in small offices.
Pagination and area spacing	Pagination is the process of composing an entire page—text, photographs, etc.—on a video display terminal linked to a typesetting computer, then typesetting the complete page on a cathode ray tube (CRT) phototypesetter or other direct output device. Area spacing is a less complex process in which all of the text material is composed on a display terminal and blank spaces (properly sized and located) are left on the page for photographs and artwork to be added by conventional page pasteup and other makeup processes.	Both processes, to varying degrees, continue to concentrate composition and typesetting work in the editorial or design area, and away from typesetting craft workers.	Pagination is presently in limited but growing use; area spacing equipment is more widely used.

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Table 1. Major technology changes in printing and publishing—Continued

Technology	Description	Labor implications	Diffusion
Data transmission	Although not a new technology, data transmission (the transmission of words, photos, etc.) is growing more sophisticated; transmitting media include microwave stations and communication satellites. Data transmission systems now can include automatic scanning and platemaking equipment which can be employed at each end of the transmission system.	The impact on labor is difficult to assess. Where data transmission systems give rise to new satellite printing plants, there will probably be an increase in demand for printing press operators. The inclusion of automatic platemaking equipment in such a system will limit the demand for platemaking craft workers.	Data transmission has been used for many years, but growing technological sophistication should promote more intensive use. Improved data transmission networks are expected to make satellite printing plants economically more feasible.
Electronic scanners for color separation	These devices electronically break down the colors in a photograph into three primary colors and black, and use this information to make a set of printing plates.	In color separation work, scanners considerably reduce the amount of time and handwork required by conventional photographic processes.	Scanners perform an estimated 25 to 50 percent of color separation work. Color separation applications should increase, especially if equipment prices decline.
Web-offset printing	This printing process uses lightweight printing plates made by a photographic process. Because of the photographic techniques used, web-offset printing is very compatible with phototypesetting technology. The actual printing is done on a continuous roll—or web—of paper (rather than on individual sheets of paper) which is folded and cut into sheets after the printing is completed.	Newspapers and other printers converting from web-letterpress to web-offset can generally retrain their press crews in the new process. Platemaking personnel also must be retrained since offset printing plates are made by a photographic process. Web-offset printing offers higher operating speeds and greater productivity than sheet-fed offset printing. Plants converting from sheet-fed offset to web-offset may have to hire or train new press crews, as the faster, more physically demanding work pace of web-offset may discourage sheet-fed press operators from accepting retraining opportunities on the web-fed equipment.	Web-offset printing is widely used in newspapers. In other areas, web-offset printing is expected to overtake sheet-fed offset printing in popularity and eventually may account for 60 percent of the total value of all offset printing, compared to about 40 percent in 1980.
Binding operations	Technology improvements include machines that combine separate binding operations; modular equipment that can be added to—or removed from—a production line as needed; and machines that have built-in controls to adjust operations. In some cases, new binding equipment uses automatic controls.	Manual handling of books and other publications during the binding process has been largely eliminated, and the need to manually adjust bindery equipment to change performance has been reduced.	These technologies are in fairly wide use and are growing rapidly.
Newspaper mailroom technology	Automatic equipment counts and stacks newspapers as they come off printing presses. Stacks of newspapers are automatically wrapped with paper or plastic and tied into bundles with wire or plastic straps. Conveyor systems move newspapers from one station to another. Automatic inserting machines insert comics and other separately printed supplements into newspapers. Central control consoles incorporating microcomputers and video display terminals can coordinate mailroom and truck dispatch operations.	Manual work and fluctuations in crew size have been greatly reduced. Employment of mailroom employees has declined. Many of the remaining mailroom employees have been trained to operate the automatic equipment.	Newspaper bundle-tying machines are widely used. Counter-stacking and inserting machines are common, although less numerous than tying machines. The use of microcomputers and video display terminals is a new development, and installations are limited.

of new technologies in composing room and other departments and their impact on printing workers are presented in the following text and in table 1.

Electronic composition

Computers for typesetting. Introduced in the early 1960's, computers are used throughout the printing industry, but approximately two-thirds of total installations are in the newspaper publishing sector. According to the American Newspaper Publishers Association (ANPA), nearly 2,000 typesetting computers were installed in member plants by 1978.[1]

The use of computers for typesetting has had a significant impact on productivity and job skills. Their application to the basic typesetting tasks of determining the length of each line of type and word hyphenation has eliminated tasks traditionally performed by skilled

[1] "Specification Data-1978," *R.I. Bulletin* (American Newspaper Publishers Association Research Institute, 1979), pp. S-13-15.

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typesetting employees. Some of these employees still use keyboards to enter the material that is to be typeset. The keyboards can be connected directly to a typesetting computer or can be part of a separate machine that puts out the magnetic or punched-paper tape that is fed into a typesetting computer. In some computerized typesetting systems, workers keypunch instructions (such as line length, type font, and spacing), then keypunch the material that is to be typeset without regard to line length or word hyphenation. The computer does the justification and hyphenation, and either puts out the material on a reel of tape that can drive an automatic typesetting machine or sends it directly (electronically) to the typesetting machine.

The earlier procedure was more labor intensive in that it required the typesetting worker to keep track of line length, and to decide on hyphenation and where to end one line and begin another. Thus the computer takes over much of the decisionmaking, thereby lowering the skill requirements for typesetting employees. Also, typesetting speeds are increased sharply because workers can type continuously, with no interruptions to end lines or hyphenate words.

New keyboards for data input. The introduction of typewriter-style keyboards into the printing industry has had a significant labor impact. Conventional printing industry keyboards used an arrangement of keys unique to the industry; consequently, only typesetting craft workers, trained to use these keyboards, could set type. However, typewriter-style keyboards used in concert with a typesetting computer enable anyone with average typing skills and a little extra training to set type. In some situations it becomes possible to completely bypass the typesetting employees: Clerical workers can keypunch material that goes through a typesetting computer to an automatic typesetting machine. Although many typesetting workers have been retrained to use the typewriter-style keyboards, and have thus retained their jobs, typesetting also is being performed by clerical workers or others who are not members of the printing craft occupations.

Video display terminals. Video display terminals are machines with typewriter-style keyboards and television-like display screens. They are widely used in business data processing applications and are being successfully applied to composition and typesetting work in the printing industry. Greater productivity, lower production costs, and expanded typesetting capability are possible when video display terminals (VDT's) are incorporated in advanced typesetting systems; but such systems also have a strong impact on employment and job skills. In general, labor requirements for typesetting operations are reduced—in part because of the greater productivity of these typesetting systems. But, most importantly, the use of video terminals allows other people, such as reporters, staff writers, and editors for many newspapers and magazines, to do their own data entry and editing as a preliminary to the material being sent, via the typesetting computer system, to automated typesetting machines.

An important early application was the use of VDT's as a data entry and correction device for tape-run phototypesetting machines, allowing operators to catch and correct typographical errors prior to running the typesetting machine. From this point, VDT's have evolved to become a necessary part of present-day electronic composition systems. Various combinations of VDT's, computerized typesetting, and automatic (predominantly photographic) typesetting machines are possible.

Phototypesetting. Phototypesetting involves setting type on film or paper by a photographic process. It is now widely used in the printing industry and has increasingly replaced the older hot-metal typesetting process. An estimated 1,000 phototypesetting machines were in use in the mid-1960's.[2] The number had grown to 10,000 in early 1973[3] and to 40,000 by 1978; it is expected to double by the early 1980's.[4]

Phototypesetting machines operate at speeds well matched to the capabilities of typesetting computers, and most can be driven by direct connection to the computer or by reels of computer-generated tape. Also, phototypesetting machines are very compatible with offset lithographic printing because lithography uses printing plates made by a photographic process. Productivity gains and changes in skill requirements can be attributed to phototypesetting, due both to its own inherent efficiency over hot-metal typesetting and to its ability to be used in combination with other modern printing technologies.

Several models of phototypesetting machines currently coexist. The earliest, rarely used today, are similar to hot-metal typesetting machines in regard to operator skill requirements and typesetting speeds—8 to 15 characters a second. More advanced "second generation" models became available that could set up to 30 characters a second. These machines are usually driven by reels of magnetic or punched-paper tape which contain typesetting instructions and text material, and operate at speeds high enough to keep several typesetting employees busy producing tape. This model

[2] *Outlook for Technology and Manpower in the Printing and Publishing Industry*, Bulletin 1774 (Bureau of Labor Statistics, 1973), p. 9.

[3] Frank Romano, "You Should Understand the Method of Typesetting by Digitization," *Inland Printer/American Lithographer*, May 1977, p. 70.

[4] Frank E. Benham, "We're Not Just Printers Anymore," *Book Production Industry*, September 1978, p. 28.

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accounts for about 90 percent of all phototypesetting machines currently in use.

The greatest advance in typesetting speed came with the development of typesetting machines that generate the type characters from computer memory and flash them onto a cathode-ray tube (CRT), where they are exposed onto film at a rate of 1,000 or more characters a second.

While the appearance of type set in some of the earlier CRT typesetters did not equal the quality of hot-metal composition, refinements in CRT photocomposition technology have greatly improved typographic results in recent years.

Development work is being performed on typesetting machines that use digitized character information to direct a laser that inscribes directly onto photo material. Such improvement in phototypesetting machines will contribute to more sophisticated pagination (full-page composition) systems—and these systems have a potential for considerable composition capacity with minimal labor requirements.

One of the most popular equipment combinations is a system that brings together a second-generation phototypesetting machine and a direct-entry video terminal which incorporates a microprocessor-based program for automatic justification and hyphenation. This technology is relatively inexpensive (especially when a used phototypesetter is purchased), and is being adopted by a growing number of small printing establishments—an important form of acceptance in an industry where about 80 percent of all establishments have fewer than 20 employees. Operators of the new VDT-equipped phototypesetting systems usually require some retraining—especially if a printing firm is changing from hot-metal typesetting to phototypesetting.

Electronic scanners for typesetting

Optical character recognition (OCR) scanners have photoelectric cells arranged in a grid pattern in the electro-optical scanning head. Each photoelectric cell can sense whether the area beneath it is blank or is covered by some part of a letter or picture. The photoelectric cells respond in an on-off fashion, and the pattern of "ons" is compared to information stored in a computer memory to determine what the scanner has "read." When applied to typesetting operations, OCR scanners electronically read typed material placed in front of the scanning device. The material usually must be typed in a special format and type face recognizable to the scanner. This requires special equipment, which to some extent limits the usefulness of scanners.

The impact of typesetting scanners for composing room employees can be significant, as illustrated by the installation in the classified advertising department at a large metropolitan newspaper visited by BLS staff. In this installation, four optical scanners and about 100 typewriters with a special font designed to be read by scanners are used. Sales personnel take information on classified ads over the telephone, type it on special forms, and process these forms through the optical scanner. The information and typesetting instructions are transferred by the scanners to reels of tape that are used to operate automatic typesetting machines. Thus, printing craft workers in the newspaper's composing room are not involved in preparing the reels of tape—a departure from traditional practice which is now permitted under negotiated contract provisions.

Pagination and area spacing

A further development in electronic composition technology is "pagination," a process whereby an entire page of material, including text, photographs, artwork, advertisements, and headlines, is designed and laid out electronically on a video display terminal. Conventional makeup is time consuming and involves skilled craft workers. A newspaper page, for example, can contain several columns of news stories with different type sizes for the titles and the text; photographs; advertisements containing artwork of varying complexity; and text material in a wide assortment of type sizes and styles. All of these components must be assembled, arranged in the proper format for a complete newspaper page, then photographed for conversion to a printing plate.

Pagination systems require video display terminals with larger screens and a sophisticated computer system. Text material is called up from the computer memory or entered directly on the terminal's keyboard. Photographs and artwork previously entered into the computer memory in digital form (perhaps by using optical or laser scanners) are called up onto the screen. The material can be sized, edited, rearranged, cropped, proofed, and, when finished, sent back to the computer. The material is then ready to be sent to a phototypesetting machine where the entire page is displayed on the screen, photographed, and converted into a printing plate.

Pagination technology is a logical next step in the development of electronic composition, and is in limited commercial use at present. As pagination systems are diffused more widely, employment of printing trade craft workers may decline further. Pagination systems carry out both keyboard and makeup operations, traditionally two separate jobs, thereby reducing labor requirements of craft workers, who can concentrate both jobs into a single, and faster, operation. But the work might also be done by an editor, in which case most of the composing room craft workers—compositors as well as makeup workers—would be eliminated.

An alternative to pagination is a process called "area spacing," or "area composition." This process works in

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the same way as the pagination process, except that blank spaces are left on the page where photographs and artwork will be placed. After the page is typeset, photographs and artwork are manually pasted into place. Area spacing, therefore, requires less sophisticated computer equipment and a little more manual work than pagination.

Data transmission

Material to be typeset, including words, photos, etc., can be composed at one location and transmitted to another location for printing. This technology, although not new, has become more sophisticated over the last decade. Optical and laser scanners read copy and convert it into digital form—including, to some extent, artwork and photographs. The digital information can be transmitted over media ranging from telephone lines to communication satellites. Various types of automated equipment are available to translate the digital information back into conventional photographic negatives or printing plates.

One newspaper undergoing extensive technological change has already installed a data transmission system in which a laser scanning unit reads copy and then transmits the digitized information in several directions simultaneously. Within the same printing plant, the information goes to another laser-based machine that will automatically make a photographic negative of the copy for use in making letterpress printing plates. The information also is sent, by microwave transmission, to a satellite printing plant where offset printing plates can be cut automatically on laser platemaking equipment. From there, the information is relayed via communications satellite to other printing plants in the country.

The impact of data transmission technology on employment is difficult to assess since it would likely vary with different installations. If a data transmission/automatic platemaking system such as described above were to replace a conventional system, it could reduce labor requirements for craft workers involved in platemaking operations. However, when data are transmitted to a new satellite plant that supplements an older plant, new jobs may be created. Without some form of data transmission technology, satellite printing plants might not be feasible.

Electronic color scanners

The major application of electronic scanner technology is in color separation work in color printing, where a separate printing plate must be made for each primary color. Breaking down a composite picture (usually a color slide or negative) into its separate colors by the conventional photographic process is time consuming and expensive because of the large amount of labor of highly skilled craft workers involved.

As the demand for color printing grew rapidly, the printing industry often was pressed to find enough skilled craft workers, and color separation operations became an acute bottleneck. This is a process in which the quality of the finished product depends upon the skill levels of the craft workers.

When electronic scanners became available, they were an attractive alternative for the printing firms that could afford them. Scanners, which performed an estimated 25 percent of all color separation work in 1978,[5] and closer to 50 percent at present, eliminate much of the handwork involved in color separation, operate at higher speeds than even the most skilled craft worker can attain using conventional techniques, and turn out color separations of acceptable quality.

An example of the differences that can exist between various color separation technologies is provided by a printing firm that uses conventional color separation equipment, continuous-tone color scanners of a type that has been available for some years, and the more recently developed laser screening scanners. A craft worker using conventional camera methods can produce a set of color separations in about 2 hours; using a continuous-tone scanner, the craft worker can do the same work in about 50 minutes. Approximately 30 minutes would be required to do this work using a laser screening scanner.[6]

Web-offset printing

Web-offset printing[7] has been growing steadily, frequently replacing both web-letterpress and sheet-fed offset printing. This growth, which is expected to continue, has affected employment and skill requirements for craft workers who make printing plates and for printing press operators.

[5] Benham, "Not Just Printers," p. 30.

[6] Richard D. Warner, "Laser Screening? A Milestone in Color Separation Technology," *Inland Printer/American Lithographer*, April 1976, p. 43.

[7] "Offset" printing refers to a lithographic printing process which utilizes a lightweight, smooth printing plate that carries a photographically imposed image. The image area on the plate is chemically treated to attract special lithographic printing ink and repel water, while the non-image or background area remains untreated, and accepts a thin layer of water. When on the printing press, which is equipped with a complex ink and water system, the plate is moistened with water over all but the image area (which repels water), then inked. The greasy ink will not adhere to the non-image areas because it will not mix with the water that is already present, but it will adhere to the chemically treated image areas on the plate. The printing plate then prints onto a rubber "blanket" cylinder, which in turn prints onto paper—thus making this an "offset," rather than a direct, printing process.

There are two types of printing presses in general use today. Web-fed presses print continuously on large rolls of paper, which are cut and folded as they come off the press. Sheet-fed presses print on separate, pre-cut sheets of paper.

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The shift from web-letterpress printing (with its associated hot-metal typesetting technology) to web-offset has been most pronounced in newspapers. By the early 1970's, practically all weekly newspapers and small- to medium-circulation daily newspapers had converted from web-letterpress to web-offset. Several large daily papers have also made the conversion, and many other large dailies hesitate only because of the large expense involved in purchasing new printing presses. Three or four companies offer equipment that will convert web-letterpress equipment to web-offset operations, at a lower cost than the purchase price of printing presses. Several newspapers are exploring this option.

The compatibility of phototypesetting technology and lithographic offset printing (which uses printing plates made with a photographic process) has freed newspapers from the expensive and slow hot-metal typesetting and the heavy lead "stereotype" printing plates used in letterpress printing. Platemaking craft workers must either be retrained for the photographic platemaking process required with offset printing or be replaced. Stereotypers—the craft workers who made the lead printing plates used in letterpress printing—have been declining in number for some years, due to the growth of web-offset printing and to the development of automated stereotype platemaking machines.

Newspapers and other printing firms converting from web-letterpress to web-offset typically retrain their original press crews, as skill requirements for the two types of web-fed printing presses are similar in some respects. Two differences between these printing processes that might affect the size or composition of press crews are: (1) the lithographic offset printing process is more complex than letterpress printing, and (2) the offset printing plates only weigh a few ounces, while the stereotype plates used with web-letterpress weigh over 40 pounds.

Photosensitive plastic letterpress printing plates are available to newspapers as an alternative to web-offset conversion. These plates are made from a photographic process—which gives the newspaper compatibility with phototypesetting technology—and are used on existing, but modified, web-letterpress printing presses.

The American Newspaper Publishers Association estimates that about 1,200 daily newspapers use web-offset printing, and about 560 dailies use plastic printing plates on letterpress presses.

Changes in the relative importance of the two types of offset printing—web and sheet fed—also have affected productivity and labor. Web-offset accounted for an estimated 12 percent of the dollar value of all offset printing in 1965, grew to take in almost 40 percent of total offset work by 1975, and is expected eventually to account for 60 percent.[8] Among the reasons for the growing importance of web-offset are its greater productivity relative to sheet-fed presses, technical improvements in new model web presses which reduce paper waste (although it is still higher than for sheet-fed presses) and allow faster makeready operations, and more widespread diffusion of electronic color scanners, whose high operating speeds are compatible with web-offset printing. Further technological improvements, such as automatic register controls and remote ink fountain controls, are now reaching the market and will promote even greater use of web-offset.

The change from sheet-fed to web-fed offset presses has changed pressroom activities from a labor-paced operation to a machine-paced operation. The design and higher operating speeds of web presses require faster decisionmaking and greater physical effort by press operating crews. The change in the pace of work and the retraining required have made some sheet-fed press operators reluctant or unwilling to switch to web presses—especially when sheet-fed presses are still in wide use. Thus, the conversion from sheet-fed offset to web-offset often requires the training of new press crews, rather than retraining existing sheet-fed press crews.

Along with the growth in web-offset printing, there has been growth in flexographic and gravure printing. Flexographic printing utilizes rubber letterpress-type printing plates and fast-drying ink, usually on web-fed printing presses. Flexography is widely used to print labels, wrappers, and paperback books. Improvements in the reproduction quality of flexographic printing have created interest among some newspaper publishers.

Gravure printing involves inscribing an image into the surface of a large metal printing cylinder. In the past, this has been an expensive, labor-intensive, high-quality process used for long printing runs, especially when color printing has been used. New technologies, such as the use of lasers to inscribe the printing cylinders, have decreased the cost, preparation time, and labor requirements for photoengraving employees. Gravure printing is growing rapidly in periodical printing, and is also growing in various commercial printing applications.

Binding technology

A number of improvements in technology are increasing the productivity of binding operations. Man-

[8] Solomon R. Kunis, "Web Offset: The Future is Bright for Printers in this Sector," *Inland Printer/American Lithographer*, May 1978, pp. 35-36.

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ual handling of books and other publications is being reduced by new types of bindery equipment that can perform several previously separate operations, such as collating, gluing, slitting, numbering, and delivering counted units ready for packaging. Increasingly, automatic controls are being applied to equipment for loading, feeding, stitching, casemaking, and stamping operations. Production equipment also is being designed that incorporates controls that permit faster adjustment of equipment prior to operation, thereby eliminating the manual tasks and the handtools required on earlier models. The flexibility of bindery production lines has been improved by incorporating modular equipment, such as rollaway stitchers and folder units, that can be added or removed from a bindery line. Efforts are underway to combine printing and binding operations into a more unified production line, reducing handling and storage of the product between operations.

Emphasis on productivity improvement is expected to continue in bindery operations. No radical technological improvements are expected, but incremental improvements should continue that can have a significant cumulative impact toward reducing labor requirements.

Newspaper mailroom technology

Technological changes in mailrooms have improved productivity and reduced labor requirements substantially. As newspapers come off the printing presses, they are counted, stacked in bundles, wrapped, then tied with wire or plastic bands. This time-consuming and labor-intensive sequence of production tasks has been carried out by semiskilled manual workers. Inserting special sections into newspapers (such as the Sunday comics) also has been done manually—which is not only labor intensive, but also requires a work crew that varies in size from day to day, depending upon the amount of inserting necessary.

The introduction of automatic equipment to do much of this work—counting, stacking, moving by conveyors, bundle wrapping and tying, and some inserting—has had a dramatic impact on mailroom employees. Skill requirements for many mailroom employees have changed from doing semiskilled manual work to operating and maintaining fairly sophisticated mechanical equipment, a change which has required the introduction of training programs. The automatic equipment has considerably reduced the number of people required to operate mailrooms, and also has reduced fluctuations in work crew size.

Output and Productivity Outlook

Output

Output in the printing and publishing industry (Federal Reserve Board data[9]) grew by an average annual rate of 3.4 percent between 1960 and 1981. (The FRB index has limitations and therefore should be considered only as a rough indication of output movement.) Demand for books, newspapers, and other printed material rose over this period as population, business activity, income levels, and leisure time increased. As shown in table 2, growth was more rapid between 1960 and 1967 (an average of 5.4 percent annually) than during the later and longer period from 1967 to 1981 (an average of 2.6 percent annually). From 1974 through 1981, however, the annual growth rate in output accelerated to 3.4 percent even though output declined by 4 percent from 1974 to 1975 as the economy turned downward.

Output in the Nation's more than 10,000 daily and weekly newspapers increased at a rather slow 1.5 percent a year during 1960-81. Output grew steadily from 1960 to 1967, averaging 4.2 percent a year. Between 1967 and 1981, however, output fluctuated considerably, reaching a peak in 1973 and again in 1979. Output increased at an annual rate of only 0.4 percent during 1967-81; growth was strongest during the late 1970's. According to the U.S. Department of Commerce, constant-dollar receipts for the newspaper segment of the printing industry are projected to maintain an annual growth rate of 3.2 percent through 1986.[10]

Output in the periodicals, books, and greeting cards sector has been increasing, and demand for periodicals and books is expected to remain high during the 1980's. Between 1960 and 1981, output increased at an annual rate of 3.0 percent; gains were particularly strong during 1960-67, at an annual rate of 5.2 percent. However, the rate of increase slowed to 1.9 percent during 1967-81. Within this period, output rose at an annual rate of 2.8 percent during 1974-81, compared to a substantially lower 1.5-percent annual rate in 1967-74.

Output gains in job printing, which includes the large commercial printing sector, have been particularly strong. In 1960-81, output rose at an annual rate of 4.8 percent. Output in job printing has followed the industry trend of increasing more rapidly from 1960 to 1967 (6.3 percent annually) compared to the more recent 1967-81 period (4.2 percent annually). The outlook for commercial printing is favorable; the U.S. Department of Commerce projects an annual growth rate of 3.2 percent in constant-dollar receipts through 1986.[11]

Productivity

Because of limitations of available data, productivity measures for the printing industry are not published by

[9] The Federal Reserve Board (FRB) production indexes are subdivided into three groups: Newspapers (SIC 271); book, periodical, and greeting card printing (SIC 272,3,7); and job printing (SIC 274-6,8,9).

[10] *1982 U.S. Industrial Outlook* (U.S. Department of Commerce, Industry and Trade Administration, 1981), p. 80.

[11] *Industrial Outlook*, p. 89.

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Table 2. Output in total printing and publishing and major sectors, selected periods, 1960-81

SIC	Industry sector	Average annual percent change[1]		
		1960-81	1960-67	1967-81
27	Total printing and publishing	3.4	5.4	2.6
271	Newspapers	1.5	4.2	.4
272,3,7	Periodicals, books and greeting cards	3.0	5.2	1.9
274-6,8,9	Job printing	4.8	6.3	4.2

[1] Least squares trend method.
SOURCE: Board of Govenors of the Federal Reserve System.

BLS. However, some improvement in output per employee is suggested by comparing trends in data on output from the Federal Reserve Board and employment from BLS. Between 1960 and 1981, output increased at an average annual rate of 3.4 percent, substantially higher than the average annual rate of increase in employment of 1.5 percent. The new printing technologies, described earlier, contributed to the apparent gains in printing industry productivity, although the extent of their impact cannot be measured precisely.

Investment

Expenditures for new plant and equipment increased rapidly during the early 1960's, reached a peak in the mid-1960's, and gradually declined afterward. Total expenditures (in constant 1972 dollars) grew from $667 million in 1960 to $1,237 million in 1967—an annual average increase of 10.9 percent over the 7-year period. By 1976, the level of capital expenditures was down to $889 million. This represents an annual growth rate averaging only 1.6 percent between 1960 and 1976, and an average decline of 3.4 percent a year between 1967 and 1976.

In 1960, about 39 percent of total expenditures were for new plants. Plant expenditures grew most rapidly during the mid-1960's and accounted for approximately 44 percent of total annual expenditures by 1967. During the late 1960's and especially during the 1970's, new plant expenditures declined rapidly; in 1976 they constituted less than 20 percent of the total.

Employment and Occupational Trends

Employment

Employment in printing and publishing grew to 1.3 million in 1981—up by 41 percent over 1960. The annual growth rate in employment over this period—1.5 percent—was lower than the 2.0 percent annual rate achieved during 1960-67, but higher than the 1.3 percent annual rate recorded during 1967-81. Employment increased steadily during the 1960's, stabilized between 1971 and 1975, which included a period of business slowdown, and rose sharply from 1976 to 1981 as demand for printed products intensified. Employment is projected by BLS to increase at an annual rate ranging from 1.0 percent to 1.9 percent during 1981-90.[12]

Production workers are a significantly smaller part of printing industry employment than in all manufacturing; even so, their importance in the industry is declining. In 1960, production workers accounted for 65 percent of printing industry employment and 75 percent of employment for all manufacturing. By 1981, production workers had declined to 55 percent of the printing industry's employees. There was also a decline in the proportion of production workers in all manufacturing—down to 70 percent of total employment in 1981, but this was not as great as the decline experienced in the printing industry.

Employment of women in the printing industry increased from 256,800 in 1960 to 513,900 in 1981—a gain of 100 percent (compared to a 41-percent increase in total printing industry employment). Women thus increased as a percentage of the industry work force—from 28 percent of all employees in 1960 to 40 percent in 1981. Electronic typesetting technology, with its use of typewriter-style keyboards and the shift of many typesetting operations from the composing room to the front office, is responsible for part of this increase.

Newspaper publishing (SIC 271) accounts for about one-third of the industry's employment. Employment in the newspaper sector grew fairly steadily from 325,200 in 1960 to a peak of 432,000 in 1981, an average annual rate of 1.3 percent. Production worker employment in newspaper publishing has been more volatile than that of all employees. Production workers peaked in 1972 and declined at an average annual rate of 1.3 percent between 1972 and 1981 to a level just slightly below that of 1960.

Commercial printing (SIC 275) also accounts for approximately one-third of the printing industry's employment. The employment situation for this sector has been slightly stronger than for newspapers: Employment grew fairly steadily from 1960 to 1981 at an average annual rate of 1.7 percent. In 1971 and again in 1974-75, employment dropped, then resumed its growth,

[12] Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy, developed by BLS. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high-trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. Greater detail on assumptions is available in the August 1981 issue of the *Monthly Labor Review*.

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peaking at 432,500 employees in 1981. Production worker employment has followed the same general pattern, but at a lower average annual growth rate of 1.3 percent.

The two major segments of commercial printing are the letterpress sector (SIC 2751) and the lithographic sector (SIC 2752). In 1960, the letterpress process dominated commercial printing, with 69 percent of employment; the lithographic portion accounted for 28 percent. As the importance of lithographic printing grew during the 1960's and 1970's, these proportions changed. In 1970, letterpress accounted for 58 percent and lithography had grown to 37 percent. By 1981, lithography had become the dominant process, with 55 percent of employment.

Occupations

Technological and other changes are expected to alter the structure of occupations in the printing industry by 1990. Substantial employment gains are projected by BLS for professional and technical workers and for sales workers. Smaller increases are projected for managers, officials, and proprietors, clerical workers, and craft workers. The remaining occupational groups —operatives, service workers, and laborers—are expected to decline.

Although the labor impact of new printing technologies cannot be measured precisely, electronic composition and other innovations are having a significant effect on the structure of occupations. Those primarily being affected are the more than 300,000 printing craft workers who make up 25 percent of the printing industry work force.[13] About 40 percent of printing craft workers are employed in the composing room where electronic composition technologies, described earlier, are being introduced more widely.

Between 1978 and 1990, a period when total printing industry employment is projected to rise, printing craft workers are expected to decline by 3 percent. Compositors and typesetters—projected to decline by 24 percent over this period—will be particularly hard hit by diffusion of typesetting computers, video terminals, optical scanners, and high-speed phototypesetting machines.

The growth of lithographic (offset) printing in newspaper and commercial printing is another innovation which has had a significant impact on printing craft workers. As offset printing grew in importance during the 1970's, employment in lithographic occupations rose steadily, and continued gains are forecast for the 1980's. In contrast, occupations associated with traditional letterpress (or hot-metal) printing have been declining. Between 1978 and 1990, for example, electrotypers and stereotypers, who make plates used in letterpress printing, are projected to decline by 56 percent.

Several occupations in the professional and technical group are being affected by new technology. As electronic computers continue to be employed more widely in the printing industry during the 1980's, employment in computer-related occupations will continue to rise. Between 1978 and 1990, computer programmers, systems analysts, and other computer specialists are projected by BLS to increase by nearly 50 percent, but they will still account for less than 1 percent of industry employment in 1990. In a few printing firms, employees displaced in composing rooms and elsewhere are being retrained for new computer positions. The shift to electronic composition also has modified job duties of editors and reporters, who are the largest single occupation in the professional and technical group, and in 1978 made up 9 percent of total employment in printing and publishing. Newspapers have installed electronic composition equipment more extensively than other firms in the printing industry, and also employ about two-thirds of all editors and reporters.

Adjusment of workers to technological change

Printing industry unions have been generally receptive to the introduction of new technology, as long as they could maintain some control over those processes that affect the jobs of their members. The unions have long sponsored extensive training programs, believing that job security, opportunities for advancement, or work in other areas for those displaced by technology would go to the most skilled workers. In addition to training programs, the unions have worked toward establishing, in collective bargaining contracts, jurisdiction for their members over the operation of new equipment. Some of the contracts have been so specific that the brand names of some types of equipment were listed. Other common provisions in collective bargaining contracts include advance notification by the company when it plans to install new equipment, and procedures dealing with retraining rights, layoffs, and severance pay. Newspaper Guild contracts typically forbid dismissals that would result from automation. Some of the technologies that have emerged over the past 10-15 years are a source of concern to the printing industry unions because they significantly reduce labor requirements in several occupations. Thus, retraining and other traditional responses to new technology may not be adequate to protect the jobs of many union craft workers.

[13] Printing craft workers include bookbinders, compositors and typesetters, electrotypers, stereotypers, engravers (except photoengravers), photoengravers, lithographers, and printing press operators and apprentices. The non-printing-trade craft workers, who in 1978 constituted about 5 percent of all craft workers in the printing and publishing industry, include construction craft workers, metal working craft workers, mechanics, repairers, and installers, transportation and public utility craft workers, and a variety of other craft workers.

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The International Typographical Union (ITU) has a policy of favoring technological change as long as the interests of its members are not disregarded. The ITU also maintains a large and very complete training center which provides courses in all printing operations, including computerized typesetting and the use of video display terminals. During the 1960's, the ITU was busy retraining its members to work with typesetting computers and tape-operated photypesetting equipment. This was a period when the ITU rejected the concept of attrition as a means of handling job displacement. Industry output was growing rapidly enough so that, along with retraining where necessary, the union was able to maintain jobs for its members.

During the 1970's, the situation faced by the ITU was different. The growing use of video display terminals and optical scanners, linked to typesetting computers, eliminated a number of keyboard jobs. ITU estimates that 25 percent of the composing room jobs held by its members were lost in newspapers that make intensive use of VDT and OCR for keyboarding operations. To meet this situation, ITU is pursuing a policy of preserving as many jobs as possible. Incentive (early) retirement plans for older workers and incentive severance (buy-out) plans for younger members are sometimes used to reduce the number of craft workers—in return for which employers contractually agree to guaranteed lifetime jobs for remaining workers. Also, a smaller number of apprentices are being admitted into the union. These policies will probably be needed for some time, as the number of compositors and typesetters is projected to decline during the 1980's.

The Graphic Arts International Union (GAIU) has also expressed concern over the effects of technological change, predicting that workers will need to be retrained several times during their careers because of changes in job skills. GAIU supports an active training program, presently including about 60 programs at various locations throughout the country. GAIU members are mostly lithographers and photoengravers, whose employment increased during the 1970's and is expected to continue to grow throughout the 1980's.

Electronic color scanners have had an impact on some GAIU members. The use of scanners does reduce labor requirements in color separation work, but the volume of the output is so great as to sometimes cause bottlenecks further along in the process, in stripping and layout work. GAIU has responded to this problem by retraining some of its potentially displaced members to operate the scanners, and retraining others to do stripping and layout work. If, in the future, retraining ceases to be adequate by itself, the union is prepared to accept attrition and the placing of limits on the entry of apprentices as methods to prevent overcrowding in the industry. However, the demand for four-color printing is increasing tremendously, in part as a result of the productiveness of electronic scanners, and the impact on the work force is still unclear.

One large newspaper visited by BLS staff had negotiated a new contract with its International Typographical Union local in 1974 that gave the newspaper the right to use original keyboarding of news copy for typesetting purposes. This allowed a reporter or staff writer to type up a news article on a computer terminal keyboard that could be used to operate an automatic tape-run typesetting machine. There was no longer any technological or contractual need for a typesetting craft worker to retype a news story for typesetting purposes. In return for the right to "capture original keystrokes," the newspaper guaranteed lifetime jobs to the printing craft workers. Within 2 years, the newspaper had an electronic composition system in place that included typesetting computers and a network of video display terminals.

In the 6 years following the new contract, the number of composing room craft workers declined from over 700 to about 480. Some of this decline resulted from regular attrition. Roughly three-quarters of the decline came about through the newspaper's policy of "buying out" (offering incentive severance pay) the jobs of printers who were willing to exchange the lifetime job guarantee for a cash sum. Other craft workers were being retrained in other areas of work within the newspaper, and were working in data processing, production, and sales positions.

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Technology and Labor in Telephone Communications

Micheal D. Dymmel

Summary

Technological change is affecting every segment of the telephone communication industry (SIC 481), considerably altering the job content and skill levels of industry occupations. Efficient electronic switching systems, higher capacity transmission systems, and increasing automation will contribute to rising output levels while decreasing the labor content of the communications process. In addition, alternate methods (domestic satellites) and forms (computer data traffic) of communication are in active use.

Due primarily to technological change, productivity growth averaged 5.5 percent annually from 1960 to 1977, well above the average for the total private economy. The growth rate was 5.8 percent for both 1960–67 and 1967–77. Current growth trends of output and employee hours indicate continued high productivity in coming years associated with expanding use of the newest technological developments.

Expenditures for telephone plant and equipment more than quadrupled to $14.4 billion between 1960 and 1977. After accounting for the very substantial construction cost increases over this period, real expenditures roughly doubled. Although sensitive to general economic conditions, expenditures will likely be maintained to provide sufficient system growth to meet continually increasing demands.

Employment totalled 992,400 in 1978, having increased by an average of 2.5 percent annually from 1960. This rate reflected periods of strong growth combined with sharp employment declines in the early 1960's, when technological changes were at a peak, and in the 1974–75 recession when total employment dropped almost 50,000 by 1976. The BLS projection for employment in 1990 is for a moderate growth rate of 1.0 percent annually between 1978 and 1990, indicating that continued output growth will offset productivity growth despite the effects of technological change. Changes in occupational distribution and skill levels were perhaps greatest in the late 1950's and early 1960's, but they will continue to be significant as newer technologies and operating procedures are more widely implemented.

Industry Structure

To fully understand telephone communication technology and its labor impact, an explanation of the industry structure would be useful. The telephone industry is comprised of almost 1,600 operating telephone companies servicing over 162 million telephones. These companies, called common carriers, must serve everyone within the geographic area in which they operate.

The Bell System dominates the industry with roughly 82 percent of total telephones and 84 percent of total operating revenues. The Bell System is headed by the American Telephone and Telegraph Company (AT&T), which is a holding company with total or majority ownership of 21 operating telephone companies and minority ownership of 2 additional companies. Through these companies, Bell serves about half of the geographic area of the United States, an area which includes the more densely populated urban centers. In addition to the telephone operating companies, the Bell System includes the Western Electric Company—the manufacturing subsidiary; Bell Telephone Laboratories—the research and development subsidiary; and AT&T Long Lines, which provides long-distance service between individual operating companies.

The remaining common carriers, known as independents, primarily serve rural and suburban areas and small towns. The independents are also dominated by holding companies, the largest being the General Telephone and Electronics Corporation (GT&E), which controls over 50 percent of independent telephones. Like AT&T, GT&E also controls manufacturing subsidiaries and research laboratories. While independent companies provide long-distance service within their own territories, AT&T Long Lines provides long-distance links between territories.

In addition to the common carriers, several specialized communications carriers are now providing private-line data and voice transmission services in some high-demand areas as a result of recent Federal Communications Commission (FCC) rulings. Equipment manufacture and supply have also been opened to competition. The effect of these changes on the telecom-

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nunications industry has thus far been small (about 2 percent of revenues), but the long-run effects remain uncertain.

A major area of competition is in high-volume, long-distance service. The rates charged for service by the common carriers are based on averages of the costs of local and long-distance calling, with less costly, long-distance service, in effect, subsidizing more costly local service. Since the specialized carriers operate under different rate structures than those required of the common carriers, they are able to provide specific services to the less costly, high-volume, long-distance users at rates that more accurately reflect the lower costs of these services. As a result, the common carriers are losing revenues from this market segment. In response to this challenge to their traditional regulated monopoly standing, the common carriers have proposed changing rate structures to permit them to compete more effectively in this lower cost area. However, according to the common carriers, this would mean that to meet FCC regulated rates of return, prices in other areas of service might increase. In the area of equipment manufacture and supply, the long-standing practice has been to use only carrier-supplied equipment. In contrast, the law now permits the use of any communications equipment which is registered with the FCC as compatible with the existing network. Responding to this area of competition, the common carriers are trying a new method of telephone distribution—directly to customers for self-installation.

Technology in the 1980's

Telephone communication is in essence a combination of two processes, call switching and signal transmission. In call switching, the major development in technology is the electronic switching system (ESS), in fairly wide use now but continually evolving. In signal transmission, optical instead of electrical transmission is most important, with significant commercial use expected by the early 1980's. Basic to almost all segments of the industry is the pervasive use of computers to automate equipment

Table 3. Major technology changes in telephone communication

Technology	Description	Labor implications	Diffusion
Electronic switching systems (ESS)	High-speed, computer-based switching equipment monitors its own performance and provides advanced dialing capabilities. Call-handling capacities greatly increased over previous equipment—threefold for local ESS, fourfold for long-distance ESS.	Reduces unit labor requirements for central office equipment installers and repairers. Modular design, self-maintenance features reduce mechanical skills needed for routine maintenance; knowledge of computer-based systems and programming concepts necessary for operation and control.	Local ESS introduced in 1965; serviced nearly 25 percent of phones by 1978; nearly complete conversion projected by 2000. Long-distance ESS introduced in 1976; 50 percent coverage projected for 1985.
Transmission innovations	Millimeter waveguide: Long-distance transmission medium consisting of an underground tube through which signal-carrying radio waves are transmitted. Call-handling capacity is more than double that of most advanced existing cables.	Unit labor requirements for installation and repair personnel will be reduced, affecting long-run employment growth. Similarity to microwave relay transmission should not require major skill changes.	Undergoing field tests. Future diffusion will depend on growth in call volume on high density communication routes and optical system development.
	Fiber optic cables: Glass fiber cables combined with semiconductor light sources for very high capacity transmission. Cables are compact, resist electrical interference, and interface well with digital switching and transmission techniques. Use is feasible on long-distance and local interexchange routes.	Long-run employment growth of installation and repair workers will be affected by reduced unit labor requirements. Skill requirements may be lessened due to highly preengineered equipment.	In trial stages; application to commercial communications systems expected in 1980.
Satellite communications	Satellites serve as relay points between distant earth stations, transmitting voice, data, and television signals. Satellite systems add versatility and security to existing ground network.	Modest growth in R&D and implementation employment should result from greater utilization. Use as supplemental capacity should not affect employment on ground-based facilities.	First domestic satellite system installed in 1974, second in 1975, and third in 1976. Third system ties into nationwide telephone network; others are leased, private-line service only. International satellites linked 100 countries in 1977.
Digital transmission	Transmission of electrical pulses instead of continuous signals greatly increases capacity with minimal investment and facilitates transmission of data. Compatible with future technologies.	Reduces unit labor requirements for maintenance craft workers in the long run. Short-run growth of installation personnel may occur during changeover. Skill requirements not expected to change.	Digital links between 100 cities on microwave relay now in operation. Evolution of a primarily digital transmission network planned for late in this century.
Computer applications	New uses of stored program control facilitate switching and billing operator-assisted toll calls, answering intercept calls, maintenance and testing functions, and management information processing.	Unit labor requirements reduced in all cases; however, actual effects on employment depend on growth in service demand. Equipment operation and repair are simplified, in most cases resulting in less employee specialization but greater variety in job duties.	Operator functions converted in some high demand areas. Maintenance systems, some now in limited use, are expected to be in operation throughout the network by 1980. Management information systems expanded considerably since 1970.

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through stored program control. In general, major advances in technology substantially increase the system's capacity while requiring little, if any, additional labor.

These aspects of technological change in the telephone communications industry, their labor impact, and their diffusion are discussed in the following sections and are summarized in table 3.

Electronic switching systems

Electronic switching systems (ESS) adapt the technology of stored program control to the central office function of switching telephone calls. ESS utilizes solid-state designs with the inherent advantages of high-speed operation, high reliability, ease of maintenance, and physical compactness. This technology, first introduced to local call switching in 1965, was used for roughly 25 percent of U.S. telephones in 1978. Coverage is expected to be almost complete by the year 2000[1] as new central offices are established and as older crossbar and step-by-step switching equipment is phased out. ESS was also adapted to long-distance call switching in 1976, with conversion expected to be about 50 percent complete by 1985.[2]

Call-handling capacities are greatly increased compared to previous equipment—threefold for local and fourfold for long-distance ESS. In addition, automatic maintenance monitors locate and diagnose circuitry problems, notify operating personnel of necessary repairs, and route connections around faulty components until such repairs are made. Most ESS circuitry consists of plug-in modules that can be rapidly changed. In areas where ESS has been widely installed, central control centers may link each switching office and perform remote monitoring and maintenance functions. Moreover, ESS provides automatic dialing functions, which may be individualized simply by changing the software controlling the operation of each switching machine.

The workers mainly affected by this technology are the central office installation and maintenance craft workers. The installation of electromechanical switching equipment involved complex wiring assignments to integrate a standardized machine into varied central office operations. The tasks are greatly simplified with ESS because its software is preprogrammed to meet the specific requirements of each installation. Thus, unit labor requirements for installation are decreased as more of this function is incorporated into the manufacturing process.

Similarly, maintenance requirements with ESS are being reduced—up to two-thirds in the case of long-distance switching systems.[3] Electromechanical switching equipment requires extensive mechanical abilities and a basic knowledge of electrical circuitry. With no moving parts, however, ESS eliminates the need for mechanical skills but requires a working knowledge of electronic computer-based systems and programming concepts and greater responsibilities in job duties. Thus, the technical skills of personnel are increasing as are the educational requirements for this type of work. However, no changes in occupational classifications are anticipated.

ESS will also affect network administration clerical personnel, whose jobs involve the translation and analysis of network operating data. As this type of information becomes more sophisticated and complex with ESS, the skills of this occupational group will increase.

Since ESS and its support systems sharply increase capacity and reduce unit labor requirements, their impact on employment growth could be adverse. However, sharply increasing call volume may offset the reduced unit labor requirements of electronic switching technologies, resulting in slight increases in central office craft worker employment.

Transmission innovations

Increases in long-distance call volume, averaging 9 percent annually during the last decade,[4] have prompted the development of two innovative transmission systems—the millimeter waveguide and fiber optic cables. Using totally different technologies, both can achieve call-handling capacities far greater than existing coaxial cables and microwave relays.

The millimeter waveguide is essentially an underground tube through which signal-carrying radio waves are transmitted. It was developed as an adjunct to the video telephone, which required much more capacity than normal voice communication for its video signals. Although interest in video communication has waned, the waveguide remains a viable, long-distance transmission medium that can provide additional capacity, as call volume increases. In view of its extremely high capacity, waveguide would be installed only on high density communication routes, such as between major cities, and its diffusion would depend on call volume growth in such areas.

Optical transmission systems employ a light source (light-emitting diode) modulated by a voice or data signal, and an optical "cable" (a bundle of hair-thin glass fibers) in place of the electrical signal/copper wire concept of conventional cable systems. An optical system, in sharp contrast to existing transmission methods, has the potential for extremely high capacity, very compact

[1]Stanley Johnston, Herbert Kettler, Alan Tedesco, "Planning Local Switching Replacement with ESS: When and How?" *Bell Laboratories Record*, March 1977, p. 59.

[2]Information provided by American Telephone and Telegraph Co. officials, October 1977.

[3]"Illinois Bell Using Long-Distance Switch," *Electronics News*, January 19, 1976, p. 8.

[4]American Telephone and Telegraph Co., *Annual Report 1973*, p. 6; *Annual Report 1978*, p. 6.

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size, resistance to common electrical interference, and a high degree of compatibility with proliferating digital voice and data transmissions. In addition to usage on long-distance routes, the space savings achievable with fiber optic cables make them ideally suited to connections between central switching offices in urban areas. One such system was first tested early in 1976, and another underwent field trials in 1977 during which it actually carried commercial traffic. It is in this capacity that optical systems are first expected to be used for telephone communications starting in 1980,[5] although limited, specialized applications may occur even sooner.

Although technological problems still exist, recent breakthroughs have advanced optical systems into consideration as one of the primary transmission media of the future. Industry specialists believe that by the time substantially higher capacity is needed on the long-distance network, optical systems will have proven sufficiently reliable and cost competitive with other systems in high-density, long-distance transmission applications. During the transition period to these high capacity transmission systems, a different type of radio transmission will be used. Called single side-band (SSB), it will more than triple the capacity of the microwave network with only minor equipment modifications at transmission end points.

Significant employment changes may occur. The installation and maintenance of facilities associated with transmission systems fall in part to line and cable craft workers, a relatively small occupational group constituting roughly 5 percent of the industry work force. As is the case with ESS, the transmission innovations mentioned (waveguide, optics, and SSB) greatly increase capacity, with a corresponding decrease in unit labor requirements. These technologies, in combination with others described in following sections, may reduce employment in this occupational group. The increasing volume of calls, however, will at least moderate, if not offset, any employment declines. As transmission capacity becomes more dependent on the electronic equipment at the end points of transmission systems instead of the cable itself, a shift in emphasis from the cable crafts to the central office crafts may occur. Equipment modifications and new equipment installations may spur short-run employment increases in the central office installation crafts.

The two innovative systems are not expected to radically alter skill requirements. The millimeter waveguide is not likely to require many new skills of craft employees due to basic similarities with microwave relay transmission technology. Well established cable-laying procedures will continue to be used with only a few new techniques of aligning and joining sections of waveguide "pipe." Optical transmission systems are likely to be highly preengineered so that cable splicing may be reduced to plugging together two connectors, simplifying the skills needed for this task. In addition, transmission end point equipment will remain principally electronic in nature and not require central office skills beyond those already needed for digital transmission equipment.

[5]American Telephone and Telegraph Co., *Annual Report 1978*, p. 7.

Satellite communication

Communication via satellite began in 1965 between the United States and Europe (satellites linked about 100 countries in 1977), providing an alternative to undersea cables for international signal transmission. In operation, satellites in synchronous orbits serve as relay points for transmissions between distant earth stations, which in turn connect to the ground telephone network. Advances in semiconductor technology and microminiaturization of circuitry have increased the call-handling capability of satellites to 25 times that of the original system and increased the satellite life-span from 18 months to over 7 years.

Westar, the first domestic satellite system providing communication between points within the United States, was placed in operation in 1974 by the Western Union Telegraph Company. Consisting of two satellites and seven earth stations, it can relay 28,800 voice channels, data traffic, and color television transmission on a leased, private-line basis. Another domestic system, Comstar, a joint venture of AT&T and GT&E, began operation in 1976. It has capabilities similar to the Western Union System but ties into the nationwide telephone network. One other system is currently in use, and several more are planned.

Aside from providing additional capacity, satellite systems increase network versatility with a third transmission medium, which, in contrast to ground-based systems, has transmission costs independent of transmission distance. In addition, satellite service capacity can be shifted to reduce the load on ground facilities as peak calling demand shifts between time zones, obviating concentrations of capacity that are fully used only at certain times of day. Data traffic, video, and other types of one-way transmission will be the most important uses of satellites; voice traffic is expected to be of secondary importance due to time delays involved with transmission over such great distances (nearly 50,000 miles in the case of orbiting synchronous satellites).

The labor involved in satellite communication is primarily in the field of research and development and ranges from electrical engineers and physicists to psychologists. In addition, personnel are needed in the construction, operation, and maintenance of earth stations. Modest employment growth can be expected in these and associated occupations as satellite use becomes more extensive. Since satellites provide only supplemental capacity, their use does not greatly affect the personnel associated with ground-based transmission facilities.

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Digital transmission

The major factor underlying the growing interest in digital transmission is the basic need for increased transmission capacity at minimal cost.

In allowing up to 24 simultaneous calls on a single communication channel, digital transmission was developed in the 1940's as a method of increasing the capacities of existing transmission systems at minimal cost. While conventional transmission is in analog form—continuous signals each occupying a single communication channel—digital transmission converts analog signals into electronic pulses, combines them with others for transmission, then decodes and reconverts them to analog form upon reception. Industry plans call for the evolution of a primarily digital transmission network by the end of this century with the utilization of long-distance ESS, millimeter waveguide, and fiber optic cables. Aiding in the transition is a relatively new technique that transmits digital data and normal voice traffic simultaneously on the nationwide microwave relay network, making the construction of separate digital facilities unnecessary. This system now links nearly 100 cities and could be expanded to the entire microwave network.

Computer data traffic, although minimal at present, is expected to increase at an annual rate of 35 percent through 1985.[6] And, although growth in the absolute volume of voice traffic is expected to exceed that of data traffic for the foreseeable future, the impact of data communications on the industry cannot be discounted.

The conversion to a telephone network based on digital transmission will affect employment as the other, previously mentioned transmission technologies will, except that the impact will be much more immediate. This technology is likely to reduce employment in line and cable crafts. However, employment may increase in the central office installation crafts. Skill levels for both groups are expected to remain unchanged.

Computer applications

The impact of computer technology in the form of stored program control on the telephone industry will be far-reaching, changing some segments not previously affected and increasing efficiency in other areas. Office administrative tasks were the first to undergo automation in the late 1950's, and various refinements in full-scale data processing systems are still being made. Numerous management information systems have evolved that automate the processing of customer records, keep inventory records, assign plant facilities, and perform various analyses on pertinent data. Clerical personnel will continue to be affected by these systems.

Currently, stored program control is being applied to more operating aspects of telephone communications than ever before. Undergoing automation are operations such as switching and billing toll calls, interception of calls to nonworking numbers, and maintenance testing systems.

The operator's duties are being changed by an electronic console which automates most of the switching and billing tasks on operator-assisted long-distance calls. This equipment can increase operator efficiency by about 25 percent and has altered the toll operator's routine job to a more varied one which requires less physical effort, somewhat more imagination and responsibility, and different, but not necessarily more complex skills. About 75 percent of telephones, in primarily urban areas, are presently serviced by this equipment. Its diffusion will increase as new methods are developed allowing remote centralized coverage of large rural areas.

An innovation which eliminates the need for one group of operators is a device which automatically answers intercept calls (vacant, changed, or disconnected numbers) with a computer-assembled voice response explaining the reason for interception and giving new number information. Although intercept operators constitute a small proportion of all operators, this equipment completely eliminates their function. Automatic intercept is currently in use only in large metropolitan areas where demand is greatest; however, systemwide implementation is expected. In addition, a system to automate coin telephones will be put into effect shortly that will monitor and compute charges on coin phone calls without operator contact, thus eliminating another operator function.

Perhaps most significant are the computerized maintenance, quality-control systems now in various stages of development. One system, expected to be in use nationwide by 1980, tests trunk lines, analyzing problems of signal loss and noise. Affecting line and cable repairers, this system can increase by a factor of 25 the number of lines tested in a typical time period.[7] Central office craft workers are being similarly affected by computerized systems. One such system, now in use, tests crossbar switching networks, locating and analyzing problems that limit switching capacity. Another system, called computerized line assignment, designates wiring attachments on central office main distributing frames to ensure proper load-balancing conditions and reduce wiring congestion.

Another important maintenance, quality-control system is now being installed. It is a computerized line status verifier which is expected to eliminate one of the top plant craft positions—the test desk operator. Under the conventional testing system, this central office job

[6]Frederick G. Withington, "Beyond 1984: A Technology Forecast," *Datamation*, January 1975, p. 73.

[7]"Accentuate the Practical," *Bell Telephone Magazine*, March–April 1974, p. 30.

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requires experience in both inside and outside plant crafts and involves testing lines and switching equipment to find customer-reported problems. The computerized line status verifier performs most of these tests automatically, reducing the work of the test desk operator by roughly 60 percent,[8] and is operated by someone of clerical status.

"No end in sight" has been said to describe expectations for future computer use in the telephone industry. Minicomputers and microprocessors integrated directly into equipment will be commonplace. An example of this is a proposed revenue accounting system based on computer circuits built into individual telephones to provide immediate revenue information. Another built-in system would allow customers to perform certain quality tests on their own telephones, decreasing the involvement of telephone repairers in the maintenance process. A step in this direction will be taken soon with the introduction of the electronic telephone set that replaces most of the mechanical parts of the older telephone sets with integrated circuits, and provides higher quality at lower cost.

As is evident from the foregoing, increased computer use will significantly affect labor since it acts to reduce unit labor requirements in almost all its applications. However, the actual effects on employment will depend greatly on changes in demand.

Production and Productivity Outlook

Output

Output in the telephone communication industry, measured in terms of real operating revenue[9], more than tripled between 1960 and 1977. The rate of increase was relatively steady at 8.1 percent annually, continuing the upward growth pattern of the 1950's. Output advanced at 8.2 percent per year during 1960–67 and at an annual rate of 7.6 percent during 1967–77. The lower rate in the later period was due primarily to the 1970–71 and 1974–75 economic recessions when output growth dropped somewhat to the still relatively high rates of 5.1 percent and 3.1 percent, respectively.

The rapid output growth rate since 1960 resulted from the more than doubling of the number of telephones in service to over 162 million and a substantial increase in usage per telephone. Various social and demographic factors have been primary causes of both these increases. Among these are the trend toward single-member households as children leave home at an earlier age; rising income levels; increasing population mobility; and an increasing reliance on communications by business and government.

The outlook is for continued strong output growth as residential and business demand increases. Although the slower population growth rate could moderate growth in demand in the long run, it is expected to be offset by continuing societal changes leading to increases in the number of households. Other factors will also contribute to output growth, such as rising income levels, proportionately larger increases in long-distance calls compared to local calls, and growth in data communications. Unknown at this point, however, is what effects competition will have on industry prices and output growth.

In addition to normal demand growth, new markets for communication services are expected to develop very rapidly in the next decade. Electronic funds transfer systems, an electronic postal service, and home data processing are important examples of future, nontraditional uses of the telephone network.

Productivity growth

Output per employee hour in the telephone communication industry grew at an average annual rate of 5.5 percent between 1960 and 1977, well above the average for the total private economy. The rate was 5.8 percent per year during both 1960–67 and 1967–77. In the 7 years from 1970 to 1977 however, productivity grew at a 7.1-percent annual rate. It advanced even more rapidly in the late 1950's, averaging 9.2 percent annually from 1955 to 1960.[10]

Changes in the rate of productivity growth have been largely associated with changes in employee hours, since output, as previously indicated, moved up relatively steadily. In the late 1950's, for example, the peak growth in productivity resulted mainly from reduced employee hours due to changeovers to automatic dial systems and electronic data processing. Hours remained fairly constant through the first half of the 1960's but were erratic in subsequent years. They began rising in the mid-1960's as employment expanded in the relatively labor-intensive occupations of installation and repair, necessary to the maintenance of the growing system.

On the other hand, employee hour growth slowed in the early 1970's as a result of reduced labor requirements realized from newer technologies and in response to tightening economic conditions. During the economic recession of the mid-1970's, hours declined more sharply than at any time since 1958, while output continued to rise at a relatively steady rate. In summary, following a decline of 0.5 percent annually from 1960 to 1963, hours increased at 4.1 percent per year during 1963–70 but then dropped to 0.3 percent annually from 1970 to 1977.

[8]"Data Processing—Burning Through the Bog", *Bell Telephone Magazine*, March–April 1976, p. 16.

[9]The output of the industry is defined as the real value of operating revenues of all telephone carriers with $1 million or more in annual revenue reporting each year to the Federal Communications Commission (FCC); and of selected large carriers, not subject to reporting requirements, for which the FCC reports the data. The real value of operating revenue is derived by appropriate deflation procedures.

[10]*Productivity Indexes for Selected Industries, 1978 Edition*, Bulletin 2002 (Bureau of Labor Statistics, 1978), p. 106. Rates are derived by the linear least squares trend method using annual indexes.

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Investment

Capital expenditures

Current-dollar expenditures for telephone plant and equipment increased from $3.2 billion in 1960 to $14.4 billion in 1977 at an average annual rate of 10.3 percent. Similarly, the book value of total plant in service increased fourfold, nearing $130 billion at the end of 1977.[11] Of yearly expenditures, a major portion generally goes toward system growth—new telephone services for new and existing customers. Plant replacement, modernization, and customer movement account for the remainder.[12]

These data, however, reflect costs unadjusted for changes in prices. Real dollar outlays (outlays after adjustment by an implicit price deflator combining communication equipment and structures) also rose sharply from 1960 to 1977, 5.8 percent annually, more than doubling over the period. Although sensitive to general economic conditions in the short run, it is likely that real expenditures will at least maintain their current level over the next decade in order to accommodate continued industry growth in response to competitive pressure.

Between 1960 and 1976, expenditures per employee (an indication of capital intensity) averaged about $8,500 in the telephone industry, compared to about $1,200 in all manufacturing industries combined (Bureau of the Census data). The annual rates of growth of expenditures per employee however, were roughly similar—7.6 percent and 8.0 percent per year, respectively.

Funds for research and development

Research and development (R&D) activities have been instrumental in raising industry productivity and assuring the most technologically advanced telephone communication system. Although R&D data are not available for the industry as a whole, data for AT&T (which alone performed nearly 85 percent of the industry's 1977 R&D) indicate the magnitude of the research effort in this industry.

A recent survey showed that, based on expenditures, AT&T ranked as the fourth largest performer (behind major automotive and computer manufacturers) of corporate R&D in the United States in 1977, spending nearly $718 million.[13] Of annual expenditures, basic research and fundamental development generally account for roughly one-third and are performed by the Bell Telephone Laboratories for the Bell System. In addition, more specific product development and design work is done by Bell Labs for the Western Electric Company, accounting for the remaining annual R&D expenditures.

Employment and Occupational Trends

Employment trends

Employment in the telephone industry has undergone severe fluctuations in the post-World War II period due to both changing technologies and varying economic conditions. Through most of the 1950's, employment grew strongly, increasing 24 percent between 1950 and 1957. Later in the decade, the near complete diffusion of direct dialing and increasing use of electronic data processing combined with the effects of two recessions to decrease employment almost 11 percent between 1957 and 1963.

Employment rose sharply after 1963 as increasing demand for telephone service offset the effects of technological change. In the period 1960–67, employment rose an average of 2.1 percent per year in spite of the sharp decline in the early part of the period. From 1967 to 1970, employment growth averaged 5.5 percent annually, reflecting expansion in the labor-intensive craft occupations that were gaining in relative importance at that time.

Thereafter, due to the effects of newer technologies and tightening economic conditions, employment growth returned to a 1.5 percent annual rate during 1970–74. However, when these factors combined with the economic recession, employment fell 2.4 percent annually between 1974 and 1976. Employment then increased slightly in 1977 and more sharply in 1978. Thus, overall in the period 1960 to 1978, total employment rose from 706,000 to 992,400 at an average annual rate of 2.5 percent.

The outlook for employment as projected by BLS[14] is for a continuation of this upward trend at a moderate rate of 1.0 percent annually between 1978 and 1990. Underlying this projection are the expectations that, relative to the 1970's, the rates of growth of output and productivity will decrease, with productivity growth slowing slightly more than output growth.

However, some within the industry feel that, due to a changed economic climate and impending competition, reductions in labor intensity will have to continue. Thus, the peak employment levels of the 1970's may not be achieved in the 1980's, although additional labor requirements in the middle of the decade may cause employment to again start slowly rising at that time.

Nonsupervisory worker employment rose from 581,900 in 1960 to 738,800 in 1978 at an average annual

[11]American Telephone and Telegraph Company, *Annual Reports*, various years; United States Independent Telephone Association, *Independent Telephone Statistics*, various years.

[12]John G. Reynolds, "Telcos Plan $12.3 Billion Construction," *Telephone Engineer and Management*, Apr. 15, 1974, p. 77.

[13]"R&D Spending Patterns for 600 Companies," *Business Week*, July 3, 1978, p. 77.

[14]The projected data are BLS estimates of what the economy might look like in 1990, given certain assumptions, for example, a full-employment economy (4.5-percent unemployment). For further details, see *Monthly Labor Review*, Apr. 1979, pp. 3–14.

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rate of 2.0 percent. As in many other industries, non-supervisory workers decreased relative to supervisory workers, declining from 82.4 percent of total employment in 1960 to 74.5 percent in 1978.

Women workers, primarily in operator and clerical positions, have historically constituted a major portion of telephone industry employment. However, technological changes in the last two decades have adversely affected the labor-intensive occupations held by women, such as telephone operators. Jobs generally held by men in such occupations as construction, installation, and maintenance were not affected nearly as much. Thus, although the number of women workers increased almost 23 percent from 1960 to 1978, their share of total employment fell from 57.2 percent in 1960 to 50.0 percent in 1978. However, if operator employment does not decrease significantly through the 1980's, and if greater numbers of craft jobs open to women, their share of total employment may stay near 50 percent.

The employment of outside labor on contract is becoming more widespread, but its use has extended almost exclusively to the provision of secondary services such as cafeteria operation and janitorial work in telephone office buildings. Most collective bargaining agreements covering major industry occupational groups make reference to subcontracting, prohibiting its use if it provides services that can be performed by covered workers or if it would cause layoffs or part-timing of permanent employees.

Occupational trends

As previously mentioned, telephone communication has become a highly complex and automated process. Although the impact of technological change on labor may have been more severe in the past (particularly in the late 1950's), it continues to alter job content, skill levels, and occupational distribution.

In general, technological change has been very effective in reducing labor intensity in all segments of the industry, and particularly in operator and clerical occupations. But, while technological development has made the U.S. telephone system the most advanced in the world, the ability of technology to make significant additional contributions to efficiency may be reaching a peak in some operations. Nevertheless, labor intensity continues to be reduced by relegating more of the communication process to the customer. Just as the dial telephone and direct long-distance dialing removed the task of call switching from the operator to the customer, other similar changes are now taking place.

Present examples include the toll operator's electronic switching console, which allows the customer to dial special calls (collect, credit card, etc.) with only a relatively short intervention by the operator for call completion. Although not related to technology, some reductions in operator service are being accomplished in areas where charging for directory assistance has been initiated.

Similarly, telephone installation and repair are becoming less labor intensive. Changes began in this area with the prewiring of buildings for telephone service during construction. Although performed by telephone industry employees, this task is much simpler during construction than after. As a result of prewiring, a concept of customer do-it-yourself developed to take advantage of possible labor savings. The customer chooses the telephone in a retail-type establishment, takes it home, and plugs it in—effectively eliminating the functions of the telephone installer.

As for maintenance, the modular assembly of telephones, where components plug in and out, is reducing the time and skills needed for telephone repair. And, carrying the concept a step further, the technology is being developed for customer participation in the maintenance of the telephone, as mentioned in the technology section of this report. This will also alter the job content of the telephone repairer's tasks. In coming years, meeting competition in equipment supply is expected to be the primary force behind employment and occupational changes in telephone installation and repair.

Important changes will also be faced by the central office crafts, i.e., installation and repair of switching and transmission equipment, in the next decade. As discussed earlier, ESS installations, due to smaller size and increased prefabrication, are considerably less labor intensive than previous equipment, but the accelerated pace of installations could increase labor requirements. Once installed, ESS and its support systems, particularly the facility for centralized remote maintenance and control, will greatly affect the skills and labor requirements of repair personnel. On the other hand, increased modifications and installations of new types of transmission, end-point equipment may increase the requirements for craft workers in this area.

Line and cable craft workers, at one time the most highly skilled craft group, are being affected adversely by technological improvements in the local distribution plant, i.e., the lines between central offices and local subscribers. Changes such as dedicated plant (permanently installed lines and connectors in commercial and residential buildings), buried cable, and quick-connect terminals, although not as spectacular as some new technologies, will nevertheless continue to reduce both the labor requirements and skill levels of this occupational group.

In summary, as service demand continues to grow, it is generally expected that many craft occupations will increase in number through the 1980's, although only moderately due to the widespread diffusion of new technologies. According to the BLS, craft and kindred workers in the telephone industry are projected to

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increase 27 percent from the 1976 level by 1985. Clerical employment, although affected by many new computerized management information systems, is also expected to increase in response to industry growth—15 percent between 1976 and 1985. Telephone operators, once the largest single occupational group, have been declining in number since the mid-1950's. The decline however, may not continue in the 1980's if reduced labor requirements are offset by increasing service demand. Some in the industry feel that unless a new technology is discovered soon, operator employment may even increase. While clearly unit labor requirements for almost all these occupations are declining, the employment outlook will depend on the growth in demand for services.

As for the professional and technical occupations, the BLS projection is for an increase of 16 percent over the 1976 level by 1985. In this case, the continuing importance of technological advancement is expected to lead to strong growth of scientific and technical employment.

Managers and sales workers are also expected to increase by 1985. Attempting to ensure service demand growth and mindful of the newly competitive environment, the industry is at present in transition from a technology-based organization to one of greater market orientation. Increased emphasis on diversified customer services is the major goal for the coming years. Versatility will take the form of new customer equipment, already apparent in the new varieties of telephones now available, and the new types of services for both business and residential customers that were described earlier. Business and sales occupational groups will be primarily affected by expansion along these lines, and these groups are projected to achieve substantial gains in the 1980's. As shown in chart 12, the BLS projects a 38-percent gain over the 1976 level by 1985.

Adjustment of workers to technological change

Programs to protect the worker from the adverse effects of changes in equipment and methods may be incorporated into union contracts or they may be informal arrangements between labor and management. Adjustments to new technologies may relate to the worker's involvement through advance notice or knowledge of workload changes, with possibilities of retraining or transfer based on seniority rights. Where reduction in force is a possibility, seniority may be particularly important. Aid in adjustment to layoff may include various types of income maintenance such as supplementary unemployment benefits or severance pay. In general, these provisions are more prevalent and more detailed in formal contracts.

In the telephone communication industry, coverage of nonsupervisory workers by formal labor-management contracts is estimated to be essentially complete. Covering by far the largest number of workers is the Communications Workers of America (AFL-CIO); the rest are covered by smaller unions, independent or AFL-CIO affiliated. The Communications Workers estimate their coverage of telephone operators and plant craft workers to be roughly 80 percent and 60 percent, respectively.

General provisions, such as a seniority basis for layoff and recall, part-timing during slack work periods, advance notice of layoffs, and severance pay, are found in most contracts and afford some protection against the effects of technological change. Other protective provisions are also quite common. For example, in a recent BLS study of 77 telephone industry contracts covering 665,050 workers, provisions for interplant transfers and on-the-job training applied to 88 percent and 56 percent, respectively, of the workers. The most recent contract negotiations also provided a supplementary income protection plan and a reassignment pay protection plan. These provisions act to minimize employee displacement due to technological change and other causes of force reduction.

Some contracts contain provisions specifically geared to the problems of technological change. Advance notice of technological change, for example, covered about 15 percent of the workers in the aforementioned BLS study.

One agreement provided that, ". . . the Company will notify the . . . Union . . . ninety calendar days in advance of a force surplus brought about by technological change."[15] Another agreement states, "Advance estimates shall be made of employee requirements as of the date the technological change is to be made so as to determine the number of employees to be retained and to be displaced, and to permit the working out of an orderly plan of force reduction."[16] The contract then goes on to provide either transfer, leave of absence, or termination allowance to displaced employees.

Labor-management cooperation in assessing employment needs has been notably successful in the telephone industry. In one collective bargaining agreement,[17] a joint committee on technological change—formed by the company—dealt with the problems created by new technologies. Solutions to these problems included transfers, on-the-job training for other assignments, and the possibility of pensioning employees.

In general, since technological changes affected occupations with high turnover rates, such as telephone

[15]Agreement between the Michigan Bell Telephone Co. and the Communications Workers of America, Aug. 4, 1974, p. 12.

[16]Agreement between the Southern Bell Telephone and Telegraph Company and the Communications Workers of America, July 18, 1974, p. 40.

[17]Agreement between the Bell Telephone Company of Pennsylvania and the Pennsylvania Telephone Guild, July 21, 1974, "Letter Agreements", p. 4.

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operators and clerical workers, the planned use of attrition became a major factor in successfully reducing employment. As employment begins to decline in the more stable craft groups, however, increased emphasis will be placed on retraining employees for new technologies or different types of jobs, while slowly decreasing the size of the work force through attrition.

One union official commented that, while jobs are lost, people seldom are. Thus, since worker displacements are minimized, technological change as a means of raising productivity is generally accepted by telephone industry employees.[18]

[18] *Improving Productivity: Labor and Management Approaches*, Bulletin 1715 (Bureau of Labor Statistics, 1971), p. 17.

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Technology and Labor in Water Transportation

Robert V. Critchlow

Summary

Changes in technology that have made ships and cargo handling operations more productive have facilitated the substantial expansion in U.S. waterborne commerce since 1960. Containerized cargo handling technology has greatly increased the speed with which ships can be loaded and unloaded, thereby reducing the unproductive time that ships spend in port. This faster turnaround time also has reduced the amount of stevedoring work required, resulting in less employment for longshore workers.

Although merchant ship size and cargo capacities have increased, crew size aboard these ships has declined. Technological changes such as centralized engine controls, bow thrusters, improved marine coatings, and changes in food preparation have reduced labor requirements aboard ships, allowing smaller crews to operate these larger ships.

Both domestic and foreign waterborne commerce have increased since 1960. Domestic commerce, consisting primarily of bulk commodities such as coal, grain, and ore, grew by an average of 1.9 percent a year between 1960 and 1979, when it accounted for 52 percent of the tonnage carried. Foreign commerce grew more rapidly than domestic commerce, at an annual rate of 6.2 percent over this time period, and accounted for 48 percent of the total tonnage in 1979.

U.S.-flag merchant ships carried only 4 percent of the total foreign commerce into and out of the United States in 1980, a post-World War II low. The number of ships in the U.S. merchant fleet has declined substantially, from about 1,000 ships in 1960 to fewer than 600 ships in 1981. Many of the ships currently in service, however, are larger and faster than their predecessors. Total tanker capacity has more than doubled, while the number of tankers has declined by nearly one-third. Total freighter capacity is down by more than 25 percent, while the total number of freighters has declined by more than 55 percent.

Although a productivity index for water transportation (SIC 44) is not published by BLS, productivity in cargo handling operations and aboard ship has risen as the amount of cargo going through U.S. ports has increased while the number of longshore workers, the number of longshore hours worked, and average crew size aboard ships have declined.

Employment in water transportation continues to decline. In 1981, about 208,200 people were employed in the industry, down from 230,800 in 1964. BLS projections anticipate a further decline by 1990, although increases are expected in some occupations. Employment opportunities for merchant marine officers are expected to remain stable, but declines are likely for other shipboard jobs, and also for longshore workers. Longshore and seafaring unions have worked through the collective bargaining process to mitigate the impact of declining employment opportunities on their membership.

Maritime Technology

Several important technological changes have taken place in water transportaion (SIC 44) that have had an impact upon industry employment. Containerized cargo handling—the single most important innovation—has become well established. A fleet of container-carrying freighters was constructed and launched and seaports developed to handle containerized cargo. Containerization has increased productivity and reduced employment of maritime workers.

Other major changes have been increases in the size and cargo capacity of merchant ships while crew size has declined. The total number of ships in the U.S. merchant fleet (primarily cargo ships and tankers) declined almost by half between 1960 and 1981, although total cargo carrying capacity rose substantially.

Specific technological changes that have reduced labor requirements aboard ships include centralized engine controls, greater use of diesel engines, improved marine coatings, installation of bow thrusters, self-unloading equipment on bulk carriers, and improvements in food preparation. These changes and their impact on workers in the industry are discussed below and summarized in table 3.

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The impact of Technology on Labor in Five Industries.

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Table 3. Major technology changes in water transportation

Technology	Description	Labor implications	Diffusion
Cargo containerization	A cargo handling process in which cargo is packed into 20- or 40-foot containers prior to being loaded on a ship. Efficient utilization of the containerization concept requires seaports with special facilities for the handling, storing, and overland transit of containers. To carry all of their cargo in containers, ships require special designs for holds and deck storage areas.	Labor requirements for longshore workers have been greatly reduced by the introduction of containerized cargo operations. Much less time and fewer workers are needed to handle cargo stored in rectangular containers, compared to the requirements for handling separate items of general cargo. It has been estimated that 20 hours of general cargo handling could be done in 1 hour if the cargo items had previously been packed in containers. Because of the speed with which they can be unloaded and reloaded, container cargo ships spend little time in port. This changes the working and living conditions of crew members, who have longer periods at sea and less shore leave.	Containerized cargo moving into and out of the United States grew from 13.5 million long tons in 1972 to 35 million tons in 1980—or from about 30 percent to over 58 percent of all general cargo. In 1981, there were 142 ships in the U.S. merchant fleet that were designed or converted to carry containerized cargo.
Changes aboard ship: Increased cargo capacity	The cargo capacity of U.S. merchant ships increased from an average of 14,000 deadweight (dwt) tons in 1960 to 37,400 in 1980.	The number of jobs aboard U.S. merchant ships has declined by more than 50 percent since 1960, due to both a reduction in the number of ships and technological changes aboard ship. Average crew size declined from 49 in 1960 to 32 or fewer in 1981.	Most U.S. freighters built in the 1960's were of 11,000-15,000 dwt capacity, and most tankers were of 20,000-60,000 dwt capacity. During the 1970's, most freighters were over 15,000 dwt, and some of the tankers were over 60,000 dwt—including several of 200,000-300,000 dwt.
Centralized engine controls	Engine controls have been placed in one centralized location in a ship's engine room, with remote controls also located on the ship's bridge. Sophisticated sensors and instruments, and sometimes computers, are used as part of the centralized control systems.	Centralized engine controls have contributed to a reduction in the number of people who must be on continuous watch duty in a ship's engine department. Work that previously required a watch crew of 3 or 4 can be performed by 2 using centralized controls.	Almost all merchant ships built since the mid-1960's have centralized engine controls. Some older ships have been retrofitted with these controls.
Increased use of diesel engines	Fuel-efficient diesel engines—widely used in marine applications outside of the United States—are replacing the more traditional steam-turbine engines commonly used in the U.S.-flag ships.	Under certain conditions, diesel engines can be left completely unattended. No firer-water tenders are needed with diesel engines.	Diesel engines are used on only a small, but growing, number of U.S. ships.
Bow thrusters	Bow thrusters are small propellers installed in the front of ships to increase their maneuverability in congested areas in harbors and rivers.	Ships equipped with bow thrusters have less need for the services of harbor and river pilots or tugboats.	Standard equipment on many ships built in the 1970's.
Improved marine coatings	Improved coatings resists the corrosion and wear caused by exposure to salt water and weather, and reduce the growth of marine life on ship bottoms.	Deck crews have fewer maintenance chores.	Improved coatings are in widespread use.
Improvements in the steward's department	Frozen food, prepackaged in individual servings, and equipment such as microwave ovens are available abroad ships. Food storage, preparation, and eating areas have been redesigned to facilitate food preparation, cafeteria-style eating, and the cleaning and maintenance of these areas.	Smaller crew sizes, along with easier food preparation, have reduced labor requirements for cooks, bakers, and mess attendants. Four to eight people now do work that used to require ten or more.	Widely used.
Innovations aboard Great Lakes freighters	These ships have grown larger over the years, thereby increasing cargo capacity. Self-unloading equipment has been developed that allows these ships to unload more quickly, be independent of shoreside facilities, and make more trips per season.	The number of shipboard jobs has declined: A smaller number of large freighters can transport all existing cargo with no increase in the size of each ship's crew. Employment opportunities also have been diminished by a decline in the volume of Great Lakes commerce since 1960.	Larger ships have become common. Use of self-unloading equipment is growing.

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Table 3. Major technology changes in water transportation—Continued

Technology	Description	Labor implications	Diffusion
Innovations aboard barges and towboats on inland waterways	Larger barges, with greater cargo capacity, are being built. The average size and power of the towboats used to push strings of barges have been growing over the years.	Unknown, due to lack of data.	Most newer barges and towboats are larger than the older equipment.

Containerization

Containerization is a process for handling and shipping cargo that has had a dramatic impact on the productivity and employment of maritime workers, and a significant impact on ship design and port facilities. Cargo packed in 20- or 40-foot containers moves from its point of origin to its final destination in a closely integrated system of transport—including truck, rail, and ship.

For the maritime industry, the primary advantage of containerization is fast ship turnaround. The time that a ship spends in port, tied to a dock, loading and unloading cargo, is unproductive. Moving rectangular containers already loaded with cargo considerably reduces the loading and unloading time for a ship. It also reduces substantially the very labor-intensive stevedoring work performed by longshore workers, and allows larger payloads to be carried by a ship. In order to take full advantage of containerization technology, ships must be designed to carry the maximum number of containers, and seaports need special facilities and equipment to handle containers.

Containerized cargo is not a new concept; some containers were used even during World War II. Unions and shipping companies began serious discussions about containerized cargo in the late 1950's. A small, but growing, amount of cargo was shipped in containers through the early and mid-1960's. Rapid growth in container usage, however, did not occur until after 1968, when a larger number of container ships and seaports with the facilities for handling containerized cargo became available. According to the U.S. Maritime Administration, which began collecting data on containerized cargo in 1972, shipments of containerized cargo more than doubled from 1972 to 1980—from about 13.5 million long tons to almost 32 million long tons. Containerized cargo accounted for about 30 percent of all waterborne freight liner service in 1972, and for over 58 percent in 1980. The proportion will probably continue to grow during the 1980's.[1]

Longshore operations and labor requirements. Prior to the development of containerization, loading and unloading general shipboard cargo were fairly slow, labor-intensive processes that had remained largely unchanged for decades. Traditional loading procedures for general, or "break bulk," cargo involved sorting cargo items at dockside, then loading the items into a cargo sling attached to a shipboard or dockside crane which would lift the cargo items from the dock and deposit them in the ship's holds. Proper placing of the cargo items in the holds was very important for maintaining ship stability at sea and minimizing cargo damage. The basic work crew—referred to as a "gang"—included people on the dock, on the ship's deck, and in the ship's holds. The exact size and scope of functions of the gang varied in detail from one seaport to another.[2]

An entirely different process is used to handle containerized cargo. Containers are mounted on a wheeled chassis which is pulled like a truck trailer. When removed from the chassis, containers can be stacked on top of each other. Typically, containers, mounted on their chassis, are towed to the dock, where large shore-based cranes lift the containers off the chassis and load them aboard the ship. The containers are stacked inside the ship's holds and on the deck. Labor requirements are reduced—gang sizes are smaller and fewer gangs per shift are needed—and the ship is loaded much more rapidly than would be possible with the general cargo procedures described earlier. A typical West Coast gang for containerized cargo work could consist of two crane operators (who alternate on a single crane every few hours), four to six lashers, two to three drivers for the tugs that move containers to the dock area, and

[1] U.S. Department of Commerce, Maritime Administration.

[2] For West Coast longshore workers, the basic general cargo gang included a gang boss, 2 or 3 deck workers (consisting of 1 or 2 winch drivers and a hatch tender), 2 people handling the cargo sling, and 4 people in the ship's hold. (See Lincoln Fairley, *Facing Mechanization: The West Coast Longshore Plan*, Los Angeles, University of California, 1979, p. 243.) The size of the basic gang—9 to 10 workers—was considered a minimum that could not be further reduced. But employers could—and usually did—add workers to the gang: For most general cargo operations, a gang of up to 20 people was usually required; and several gangs would be assigned to the same ship, depending upon the number of hatches being worked.

The size of East Coast and Gulf Coast longshore gangs was usually set by contract negotiations at the Port of New York City. As the largest and most influential seaport, agreements reached at New York tend to set a pattern that others follow. In New York, gangs of 20 workers were used, with an agreement that the number of gangs assigned to a ship would be reduced for container ships. (See Joseph P. Goldberg, "Modernization in the Maritime Industry" in *Collective Bargaining and Technological Change in American Transportation*, Evanston, Northwestern University, 1971, p. 345.)

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a supervisor.[3] Thus the composition of the container gang is different. Further, the container gang generally does not need to be expanded, as often was necessary for the earlier dockside gang.

The use of containers increases productivity and reduces longshore labor requirements. The ratio of hours required per ton of general cargo handled to hours required per ton of containerized cargo handled is usually given as 20 to 1.[4]

Port facilities. Seaports that handle containerized cargo require special facilities and equipment. Large storage areas are needed to hold containers awaiting shipment. Extensive truck and rail facilities also are necessary to move containerized cargo into and out of the port area. Specially designed docks and shore-based cranes also are required to service container-carrying ships efficiently.

Efficient high-speed loading of containers requires the use of special, expensive cranes—the operators of which (usually longshore workers) require additional training. Most general cargo, prior to the widespread use of containers, could be handled in cargo nets or slings lifted by shipboard cargo booms and winches. Operating the winches required some training, but it was not a highly skilled job.

Training for container crane operations generally is not lengthy or difficult. The supervisor in charge of crane operations at one large East Coast container port estimated that one 8-hour day of training would be adequate to teach a person to operate a container crane safely and satisfactorily in calm weather. For windy days, or under other adverse conditions, a greater amount of training and experience would be necessary.

The same East Coast port also utilizes several older cranes designed for heavy general cargo work. Skill requirements for these cranes are much higher than those for container cranes, as operators not only raise and lower cargo, but rotate the crane on its base to move cargo from one area to another. The operator must be able to cope with front-to-rear swing, side-to-side swing, and rotation or spin as the cargo is moved. Also, the operator sits in a cab at the base of the crane's boom (on the dock). When the cargo sling is over the ship's deck or going down into the ship's hold, the crane operator cannot see it at all, and must be able to operate the crane according to signals received from another person on the ship's deck. Cranes such as these are so sturdily built that they can remain in use for many years. While they are used, they put much greater demands on operator skills than do the more modern container cranes. Some of these older cranes will continue to be used in the foreseeable future because it is impossible to containerize all forms of shipborne cargo.

[3] Fairley, *Facing Mechanization*, p. 274.
[4] Ibid.

Container-carrying ships. Containerization has had an impact on ship design. In ships which carry containerized cargo exclusively, deck areas and holds are designed for stacking 20- and 40-foot containers securely. Such specialization in ship design does maximize the number of containers a ship can carry, but it severely limits the carrying capacity for noncontainerized cargo. There are also "partial" container ships, which are designed to carry some containerized cargo and some general cargo.

Living conditions of crew members have also been affected by containerization. Because container ships can be unloaded and reloaded so quickly, they spend very little time in port. This capacity for fast turnaround in port, which makes container ships so productive, drastically reduces shore leave for crew members, and increases the time that crew members spend at sea.

Maintenance work may be slightly less for the deck crews of container ships, compared to general cargo ships. The handling of cargo containers results in less damage to paint and to bulkheads and decks in ship holds than the handling of general cargo. This can reduce, to some extent, the amount of repairing and repainting required of sailors. Some container ships do not carry cargo booms and winches, which also reduces maintenance requirements slightly.

Roll-on/roll-off (Ro-Ro) ships are a highly specialized extension of the container ship concept. These ships are designed primarily to transport containers that are still mounted on wheeled chassis (like truck trailers). Ro-Ro ships have ramps, mounted on the rear of the ship, which can be lowered onto a dock. Trucks or other small towing vehicles can pull the containers on and off the ships—hence the term "roll-on/roll-off." This allows the ships to be virtually self-loading and -unloading. They are largely independent of any need for seaport cargo-handling facilities. Because containers remain mounted on wheeled chassis, they cannot be stacked on top of one another. Therefore, fewer containers can be carried in a given space—a space penalty the Ro-Ro ships pay for their self-loading abilities. Instead of holds in which containers are stacked, Ro-Ro ships have a number of separate cargo decks in which the containers are parked. Ro-Ro ships are largely a product of the 1970's, and tend to have carrying capacity that is smaller than many modern container ships but similar to that of many general cargo ships.

Some Ro-Ro ships are designed to carry standard containers stacked on the main deck. These containers are loaded and unloaded conventionally, by crane, while the containers on wheeled chassis are rolled on and off. Ships that carry automobiles exclusively are a special development of the Ro-Ro concept. The importance of ships specifically built or converted to carry only automobiles has grown apace with international auto-

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mobile markets. Some car carriers transport as many as 5,000 cars.

The number of intermodal ships—container ships, partial container ships, and roll-on/roll-off ships—in worldwide use is growing. Few of these ships existed in the 1960's. In the 1970's, many of the new freighters built each year were container-type freighters. In 1981, the U.S.-flag intermodal fleet consisted of 142 ships.

Changes aboard ship

Technological changes and improvements have reduced labor requirements aboard merchant ships of all types. The size and cargo capacity of merchant ships have generally increased; but there has been no corresponding need to increase crew sizes to operate the larger ships. In addition, centralized engine controls and improvements in food preparation have brought about a reduction in the average size of a modern ship's crew.

Ships with greater cargo capacity. The increases in ship size and cargo capacity, along with the rapid turnaround time of container ships in port, are the main reasons for increased productivity. The 1,008 privately-owned ships in service in the U.S. merchant fleet in 1960 had a total cargo capacity of 14.1 million deadweight tons (dwt), or an average capacity of about 14,000 dwt per ship. By the end of 1981, although the size of the merchant fleet had declined to 574 ships, total deadweight tonnage had grown to 21.5 million tons—or an average of about 37,000 dwt per ship.

Most of the oceangoing U.S. merchant ships are either freighters or tankers. The relative importance of each of these types of ship has changed over the 1960-81 period.

There were 613 freighters in the U.S. merchant fleet in 1960, with 6.5 million dwt of total capacity—or an average capacity of about 11,000 dwt per ship. In 1981, there were 266 freighters with a total capacity of 4.7 million dwt—or an average of 17,500 dwt per ship. Most of the freighters built during the 1960's were general cargo carriers in the 11,000 to 15,000 dwt class. No general cargo ships were built in the United States during the 1970's; all of the new ships were container ships, barge carriers, or roll-on/roll-off ships, generally in the "15,000 dwt or over" class.

Changes in cargo capacity have been more dramatic for tankers than for freighters. In 1960, there were 388 tankers in the U.S. merchant fleet with a total capacity of 6.8 million dwt, and an average capacity of 20,000 dwt per ship. By 1981, the number of tankers had declined to 271, but total tanker capacity had grown to 15.2 million dwt, and average tanker capacity to 55,000 dwt. Thus, total tanker capacity more than doubled between 1960 and 1981, while the number of tankers declined by nearly one-third.

Smaller crews. Over the period 1960-81, when average deadweight tonnage increased by about two and one-half times, the average size of ship crews declined from 49 to 32 crew members.

The typical crew for a modern container ship would be about 37, compared to about 45 aboard a typical general cargo ship in 1960. The number of officers and the size of the deck crew are similar to a 1960 crew aboard a general cargo ship, but there are fewer people in the engine and steward's departments. The engine department now has a complement of 12. Engineers and electricians account for six people—about the same as in 1960; but there are fewer people in the lower skilled jobs of oilers, wipers, mechanics, and firer-water tenders. The steward's department has eight people, including the chief steward and two cooks. The remaining jobs are mess/utility workers—low-skilled jobs that account for most of the reduction in the size of the steward's department. The reduction in engine department crews is mostly due to changes in technology, while the smaller size of the steward's department reflects changes in technology as well as the smaller number of people for whom meals are prepared.

Additional reduction in the size of crews on freighters is possible. As an example of potential developments, one new German container ship of 33,000 dwt capacity carries a crew of only 24—1 master, 3 mates, 3 engineers, 1 radio operator, 1 electrician, 10 "multipurpose" engine-deck workers (in place of separate deck crews and engine department crews), 1 cook, 3 stewards, and 1 laundry worker.

Typical crew sizes for tankers have also changed substantially over the past two decades. In 1960, T-5 class tankers (33,000 dwt capacity) carried a crew of more than 40. This included 5-6 deck officers, 12-14 deck crew members, 16-18 in the engine department, and a steward's department of 8-9.

By the late 1970's, the T-8 class tanker entered service. This ship had a cargo capacity of 92,000 dwt—almost three times the capacity of the T-5 tanker—and a crew of only 26. The number of deck officers (5) was similar to the T-5 tanker, but all other departments were smaller. The deck crew consisted of nine people, including the bosun (supervisor) and eight able- and ordinary-class sailors (one less than carried on the T-5). There were no longer any separate deck maintenance jobs such as found on the T-5 tankers. A crew of eight was required in the engine department, including four engineers (down by one from the requirements of the T-5 ship) and four ratings—three mechanics and one pump tender. In the steward's department, there were only four people—two cooks and two mess/utility workers. As with freighters, reductions in crew sizes were largely the result of changing technology, with a secondary impact on the steward's department as a consequence of the smaller crew size.

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Centralized engine controls. A substantial amount of equipment is necessary to operate a ship's engines: Fuel and lubricating oil must be provided and the engines must be operated within temperature, pressure, and speed ranges. Moreover, pumps, pipes, valves, electrical relays, and gauges must be monitored and maintained. Steam-powered engines—the most common type on U.S. merchant ships—require that water be heated in a boiler and maintained at a particular pressure.

Traditionally, little attempt was made to centralize or simplify the locations of various controls, gauges, valves, etc. in the engine room. Engine department crew members went to wherever the controls were located to do their jobs. Typically, a crew of three or four (including a licensed engineer as watch officer) had to be on continuous watch.

With centralized controls, a crew of two can safely and adequately stand watch. Powerplant and auxiliary equipment controls, along with the necessary instrumentation to provide data on engine and propeller operations, fuel flows, pressures, temperatures, etc., can all be grouped on a central control console or at a single control station. A watch crew of two can monitor and control all engine and auxiliary functions from the control area. Sophisticated sensors and instruments can provide watch crews with data on potential problems in time to take appropriate action. Computerized engine monitoring and data storage systems are available that can monitor several hundred engine functions, maintain continuous readouts, compare performance parameters with sea-trial data to check efficiency, and keep records of all monitored functions.

Engine speed and propeller direction (forward or reverse) also can be controlled from the ship's bridge. This allows ship's officers more control over the ship's powerplant—and under some conditions can eliminate the need for any watch crew in the engine department.

The U.S. Government became involved in promoting wider use of centralized engine controls in the early 1960's, and subsequently such control systems have been built into most new ships and retrofitted onto many older ships. Federal Government funds were used to subsidize operating costs for ships under U.S. registry, as part of a program to insure that the country maintained a fleet of ships and crews for national security purposes. Most of the funds used to pay wages for ship crews were provided by the Federal subsidy, with the result that the Federal Government became very interested in reducing labor costs.

Increased use of diesel engines. Diesel engines are the most popular type of marine powerplant worldwide because their fuel economy is superior to any alternative powerplant. However, most U.S. oceangoing ships use conventional steam turbine powerplants. These engines have a long history of good service due to their simplicity and reliability—although their fuel costs are higher than for diesel engines. Due to the increases in fuel costs since 1973, diesel engines are becoming more widely used in new U.S.-built ships.

Diesel engines, when combined with remote engine controls on a ship's bridge, have the beneficial side-effect of reducing engine department watch requirements under certain conditions. When a ship is at sea (where it maintains a fairly steady speed and course), the engine room can generally be left completely unattended. Under these conditions, the remote controls and instrumentation in the ship's bridge are adequate for powerplant control. With no need to maintain a constant watch crew under these conditions, the size of the engine department crew can be reduced. Also, one job, that of the firer-water tender, is not needed for diesel engines.

Bow thrusters. The installation of bow thrusters (and, less frequently, stern thrusters) considerably increases a ship's ability to maneuver in close quarters. A bow thruster is a small propeller located at the front end of a ship's hull which is mounted perpendicular to the length of the hull. When in use, the propeller pushes the front end of the ship to the left or right, making it possible for the ship to turn more quickly or more sharply.

When a ship is equipped with a bow thruster, it can often approach or leave a dock unassisted. In contrast, two tugboats (or more, for large ships or bad weather conditions) are often used to maneuver a ship without bow thrusters through a river or harbor channel. A ship equipped with a bow thruster frequently needs the assistance of only one tugboat (in good weather)—and in some situations may be able to do without any tugboat assistance.

Marine coatings. Improvements in marine protective coatings have reduced onboard maintenance required of ship crews and also have lengthened the drydock intervals for ships. Improved paints that resist the corrosion and wear caused by exposure to weather and salt spray are being used on decks, superstructures, and hull areas above the water. These coatings have made a significant reduction in maintenance requirements involved with chipping off old paint and repainting—previously a frequent and time-consuming part of a sailor's duties.

Protective coatings for the underwater part of ship hulls reduce corrosion and growth of marine life. Use of these underwater coatings would have no direct impact on shipboard labor requirements, as such maintenance is done by periodically putting the ship into drydock. However, these coatings reduce the frequency of drydock intervals, allowing the ship to continue its regular operations for longer periods of time, which could have an indirect impact on ship crews.

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Steward's department. The steward's department on a modern ship has fewer people than in 1960. This is due in part to the generally smaller crews needed on modern ships, with a corresponding reduction in the amount of food that must be prepared. There are also some technological changes that have affected the size of the steward's department. Some food is available in prepackaged form, frozen in individual servings that are quick and easy to prepare. Food storage, preparation, and eating areas have been redesigned on some ships to reduce the movement of food from one area to another. Cooking and eating areas are designed to minimize cleaning and maintenance work. Cafeteria-style eating arrangments are now common.

As a result of these changes, the number of cooks and bakers has declined, and the chief steward's job is sometimes merged with these. Also, fewer mess attendants are now needed.

Innovations on the Great Lakes and inland waterways

Great Lakes. Freighters in service on the Great Lakes are highly specialized vessels, designed to carry bulk cargo—primarily ore, coal, and grain—through the rivers, water locks, and canals prevalent in the Great Lakes area. The ship hulls have flat sides, flat bottoms, and blunt ends, and resemble floating boxes—a very efficient design for carrying cargo.

An upper limit to the size of these ships has always been set by the size of locks on the rivers and canals through which the ships must travel. Over the years, lock sizes have increased, and increases in ship length have followed immediately. Over the past decade, ships of 800- to 1,000-foot lengths have been introduced. Some of these ships are new, but some are older, smaller vessels that have been modified. The modification consists of cutting the hull in half and welding in a new center section. One such conversion involved lengthening a 730-foot vessel to 826 feet, increasing the length by 13 percent and cargo capacity by 16 percent.[5] The larger ships are more productive, since more cargo can be transported without any increase in crew requirements.

Productivity also has been improved by the introduction of self-unloading equipment. This technology consists of a long loop-belt conveyor system which runs the length of the ship, just below the cargo holds. Ore, grain, or coal drops through openings in the bottom of the holds onto the conveyer belt, and is carried to an unloading hopper on the ship's deck. The ship also is equipped with an unloading boom. This boom, which is 250 or more feet long on the larger ships, can swing to either side of the ship. It utilizes another conveyer belt to carry the coal or ore to shore. Ships can be unloaded at a rate of 6,000 to 10,000 tons of coal or ore an hour. Unloading time can be reduced by as much as 15 hours a trip, which can allow the ship to make as many as 25 extra trips a season.

Inland waterways. Approximately 25,000 miles of river channels, lakes, canals, and reservoirs in the United States are commercially navigable. Most of the commerce on these inland waterways consists of bulk cargo, such as coal and grain, carried on barges. Groups of barges are pushed along these waterways by specially designed towboats.

Over the years, the barges used on inland waterways have become larger, reaching a maximum size of 195 feet by 35 feet. This upper limit on barge size has been imposed by the dimensions of the locks on the various rivers through which the barges must travel.

Larger, more powerful towboats have been developed to push larger groups of barges. The towboats have one to four diesel engines, each engine driving a separate propeller. In 1960, towboats averaged 5,500 horsepower; by the late 1970's, towboats with 10,000 horsepower were put in service. The larger towboats can push up to 40 barges at a time, while the more numerous smaller towboats push 10 to 15 barges.

Output and Productivity Outlook

Output

Total U.S. waterborne commerce almost doubled between 1960 and 1979, increasing from 1,100 million short tons to 2,082 million short tons.[6] As shown in table 4, the average growth rate was 3.5 percent a year over this period.

Domestic waterborne commerce increased from 761 million short tons in 1960 to 1,088 million tons in 1979, an average annual growth rate of 1.9 percent. By 1979, domestic commerce accounted for 52 percent of total waterborne commerce—down from 69 percent in 1960. Internal commerce, over rivers and other waterways, has accounted for about one-half of domestic tonnage since the late 1960's. Almost all of this commerce is bulk cargo (much of it coal) carried on barges. Coastal, Great Lakes, and local waterborne commerce account for the balance of domestic tonnage.

Foreign commerce increased at an annual rate substantially higher than that of domestic commerce. In 1960, foreign commerce amounted to 339 million short tons, or 31 percent of total U.S. waterborne commerce. By 1979, foreign commerce had grown to 993 million tons—which represented a substantially higher share—48 percent—of total commerce. Only a small

[5] "Jumboization Leads the Way to the New 1000-ft. Giants," *Marine Engineering/Log*, November 1977, pp. 47-48.

[6] Department of the Army, Corps of Engineers.

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Table 4. U.S. waterborne commerce: Rates of increase for selected periods, 1960-79

U.S. waterborne commerce	Average annual percent change[1]			
	1960-79	1960-65	1965-73	1973-79
Total commerce	3.5	3.6	3.8	3.4
Foreign	6.2	6.4	6.2	5.2
Domestic	1.9	2.2	2.3	1.8

[1] Least squares trend method.
SOURCE: Department of the Army, Corps of Engineers.

portion of foreign commerce is carried on U.S.-flag ships, and even this has declined over the last two decades. In 1960, U.S.-flag ships carried 11 percent of all U.S. oceanborne foreign trade; but by 1980, the amount transported by U.S.-flag ships was under 4 percent.[7]

The level of commerce in the Great Lakes has also declined, from 155.1 million short tons in 1960 to 142.7 million tons in 1978.[8]

Productivity

Because of data limitations, BLS does not publish an index of output per employee hour for the water transportation industry. There are, however, data available which suggest that productivity in the industry has been increasing. Total waterborne commerce in the United States increased at an average annual rate of 3.5 percent between 1964 and 1979. During this same period, according to BLS employment data, industry employment declined at an average rate of 1.2 percent a year.

In another, more specific area, U.S. Maritime Administration data show that the number of jobs available aboard U.S. oceangoing ships averaged 49 per ship in 1968, and a substantially lower 32 jobs per ship in 1981. Over this period, the average deadweight capacity per ship increased, resulting in higher capacity per crew member—one partial indicator of productivity improvement.

Employment and Occupational Trends

Employment

Employment in water transportation has been declining as the size of the U.S. merchant fleet has fallen and laborsaving innovations for cargo handling and shipboard operations have been adopted more widely. Between 1964 and 1981, employment fell from 230,800 to 208,200—an average annual rate of decline of 1.0 percent.[9] According to BLS projections based on three versions of economic growth, employment in water transportation probably will continue to decline—at an average annual rate ranging from 0.2 to 1.4 percent a year between 1981 and 1990.[10]

Employment aboard oceangoing U.S.-flag ships, according to Maritime Administration data, has declined rather sharply. Between 1967 and 1981, estimated employment in merchant marine occupations dropped from 102,000 to 35,000—a decline of 66 percent.[11] Employment has fallen for both merchant marine officers and sailors. The number of officers declined from 28,000 in 1967 to 11,000 in 1981—or by 61 percent. The number of sailors (which includes crew members in the deck, engine, and steward's departments) declined from 74,000 to 24,000 over the same period—a sharper drop of 68 percent. The declining number of ship's officers appears to be primarily the result of a shrinking U.S. merchant fleet, while the steeper decline in employment for sailors reflects the dual impact of a declining merchant fleet and the diffusion of new, laborsaving technology.

Declining employment aboard privately owned, oceangoing U.S. merchant ships is attributable primarily to a decline in the number of ships in the U.S. merchant fleet, and secondarily to the impact of new, laborsaving technology. Between 1967 and 1980, the size of the U.S. merchant fleet dropped by 41 percent. A limited, and declining, number of employment opportunities have been available on merchant ships owned by the U.S. Government. These ships, mostly in the National Defense Reserve Fleet, have sometimes been operated by civilian merchant marine personnel, whose numbers are included in the employment data for water transportation.

New technology—discussed elsewhere in this report—has reduced labor requirements and crew sizes

[7] *United States Oceanborne Foreign Trade Routes, 1977* (U.S. Department of Commerce, Maritime Administration, October 1979), p.2.

[8] *Waterborne Commerce of the United States, Calendar Year 1978,* Part 5, *National Summaries* (Department of the Army, Corps of Engineers), p.6.

[9] BLS employment data for water transportation are not available for years prior to 1964.

[10] Projections for industry employment in 1990 are based on three alternative versions of economic growth for the overall economy, developed by the Bureau of Labor Statistics. The low-trend version is based on a view of the economy marked by a decline in the rate of expansion of the labor force, continued high inflation, moderate productivity gains, and modest increases in real output and employment. In the high-trend version I, the economy is buoyed by higher labor force growth, much lower unemployment rates, higher production, and greater improvements in prices and productivity. The high-trend version II is characterized by the high GNP growth of high trend I, but assumes the same labor force as the low trend. Productivity gains are quite substantial in this alternative. Greater detail on assumptions is available in the *Monthly Labor Review* of August 1981.

[11] Maritime Administration data are based on the number of available jobs aboard ship as of June 1st of each year. Long vacations are common in this industry to balance the long periods of time spent at sea. The Maritime Administration estimates employment by adjusting the number of jobs available with ratios that reflect people on vacation as well as those currently working.

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aboard ships. In 1960, there was an average of 49 jobs per ship. By 1981, the average had declined to 32 jobs per ship. These averages reflect the jobs available on all of the ships in the U.S. oceangoing merchant fleet, regardless of age or efficiency. As indicated earlier, ships built in the 1960's and 1970's have typical crew sizes that are smaller than the average calculated for all ships currently in operation.

New technology has had a greater impact on the employment of sailors than on the employment of ship's officers. Except for a relatively small decline in the number of engineering officers, there has been little change in the size or composition of the complement of officers on merchant freighters and tankers. But there have been declines in the number of deck crew personnel, and especially in the numbers of people employed in engine and steward's departments.

Employment opportunities for longshore workers have declined as a result of productivity gains through containerization. In 1960, there were 70,500 longshore jobs. By 1981, only 45,598 existed—a decline of about 35 percent.

Employment opportunities on Great Lakes ships have declined over the past two decades. In 1960, there were 7,873 shipboard jobs available; by 1981, only 2,216 jobs were available—a decline of 72 percent. Some part of this decline is caused by the increased productivity of ships: A smaller number of larger ships, each carrying more cargo, but no more crew members.

Occupations

Employment in all of the broad major occupational groups are projected by BLS to decline by 1980. The decline projected for craft workers is only 0.2 percent—too small to be significant; and the 2.1-percent decline expected for managers (which includes ship's officers) also is small. Service workers and the already small number of sales workers, however, are expected to decline sharply.

The number of merchant marine officers should remain fairly constant through the 1980's since the size of the merchant fleet is expected to remain stable over the next decade. This occupational group includes ship captains, mates, engineers, and radio officers.

Employment opportunities for other shipboard occupations, however, are likely to decline. Sailors employed in the deck and engine departments (most of whom are in the occupational category of "operatives") and the cooks, bakers, and mess attendants (classified as service workers) in the steward's department make up the largest part of a ship's crew. While the number of ships may remain fairly stable, technology continues to change, and the newer ships use smaller crews.

Traditionally, employment has been along craft lines, with strict divisions between deck, engine, and steward's departments. New technology has blurred the distinction between some of the deck and engine department jobs. For example, during the 1970's, an occupation called "deck-engine mechanic" came into being. Job functions for a deck-engine mechanic included some of the deck department maintenance work and the work of oilers, firers-water tenders, and electricians in the engine department.

Declining crew sizes and technological changes in food preparation should continue to reduce job opportunities in the steward's department.

The use of containerized cargo should continue to grow. Such growth will probably further reduce the number of job opportunities for longshore workers—classified as a laborer occupation—since labor requirements for containerized cargo will continue to be substantially less than for general cargo. The International Longshoremen's and Warehousemen's Union, however, states that West Coast longshore employment appears to have stabilized at about 10,000.

Adjustment of workers to technological change

Longshore and seafaring unions use collective bargaining contracts to control, to an extent, the impact of technology and other changes on their members. In general, the collective bargaining process has given rise to job placement of all registered union members through hiring halls, and agreements on minimum numbers of people—under various conditions—in longshore gangs and shipboard crews. Longshore workers have been strongly affected by changes in bulk cargo handling—especially cargo containerization processes. Seafaring unions—of which there are many—have been affected both by technological changes and a decline in the number of ships in use.

On the West Coast, the International Longshoremen's and Warehousemen's Union (ILWU) bargains on a coastwide basis with the multiemployer Pacific Maritime Association. Under the Mechanization and Modernization Agreement of 1960 and subsequent modifications, the union halted restrictive work practices, thus making practical the introduction of new cargo handling technology (especially containerization). In return, the employers provided funds to handle job guarantees and severance pay upon retirement. Present contract provisions provide up to 36 hours of work or pay per week to all class "A" registered longshore workers. Thus the work force is protected from income loss due to technological change.

Labor relations are much more decentralized on the East and Gulf Coasts, where longshore workers are represented by the International Longshoremen's Association (ILA). Economic and labor conditions vary widely from one port to another. There is greater reliance upon individual union locals bargaining directly with local shipping and stevedoring companies, within the framework of a master contract. There also has

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been more strike activity and a more gradual acceptance of new, laborsaving technology by the ILA. The union negotiated a Guaranteed Annual Income (GAI) plan which is financed by an assessment on cargo, and relates both to the impact of containerization and to changes in work rules over the years, brought about by new technologies. This plan provides that all eligible employees will be paid for a specific number of hours each year, at the prevailing wage rate, even if this much work is not available.

Some containers—20 percent or less—are loaded and unloaded at or near seaports. Both longshore unions have tried to maintain jurisdiction over as much of this work as possible. On the West Coast, the ILWU has encountered some jurisdictional problems with the International Brotherhood of Teamsters (IBT): Freight forwarding companies that haul containers to and from seaports also do some loading and unloading of containers at their warehouses. The work is performed either by IBT members or by unorganized workers who also drive the trucks that haul the containers. The ILA has approached the problem by negotiating to have most containers coming from or going to a point within 50 miles of the shipping port loaded or unloaded at a waterfront facility by ILA members.

Collective bargaining is more complex for seafaring employees because of the large number of unions involved. Most ship officers are members of a maritime union, the largest of which are the International Organization of Masters, Mates and Pilots; and the National Marine Engineers Beneficial Association. There are at least five smaller unions that represent pursers and radio operators. Unlicensed personnel are represented by the National Maritime Union of America, the Seafarer's International Union of North America, the Sailor's Union of the Pacific, and the Marine Firemen.

Faced with declining employment opportunities, seafaring unions have worked out a number of programs. Each union tries to establish areas of clear jurisdiction. Hiring for licensed and unlicensed personnel is done through registration and job allocation in hiring halls, where employment opportunities are equalized somewhat by giving job preference to those who have been unemployed longest. Most of the unions have training programs for entry or advancement in jobs.

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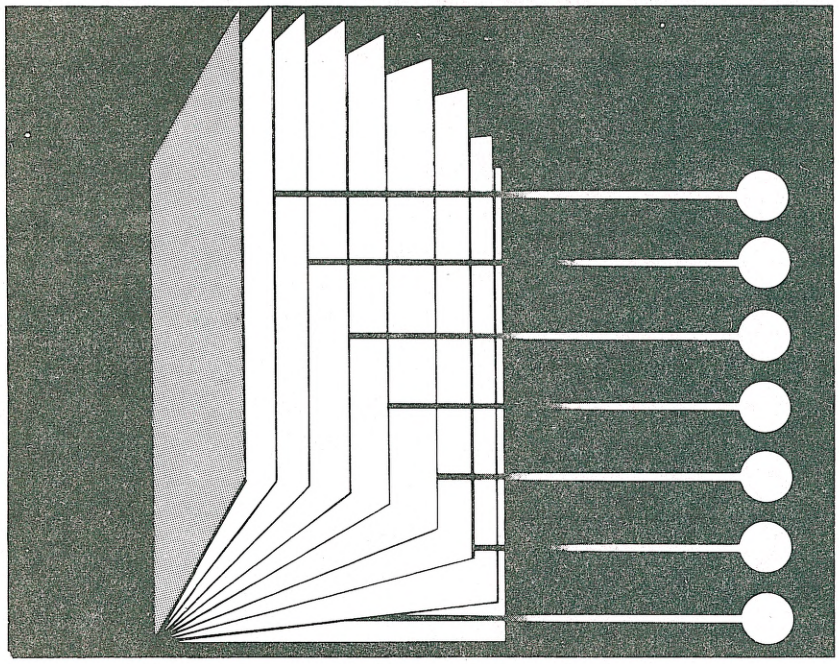

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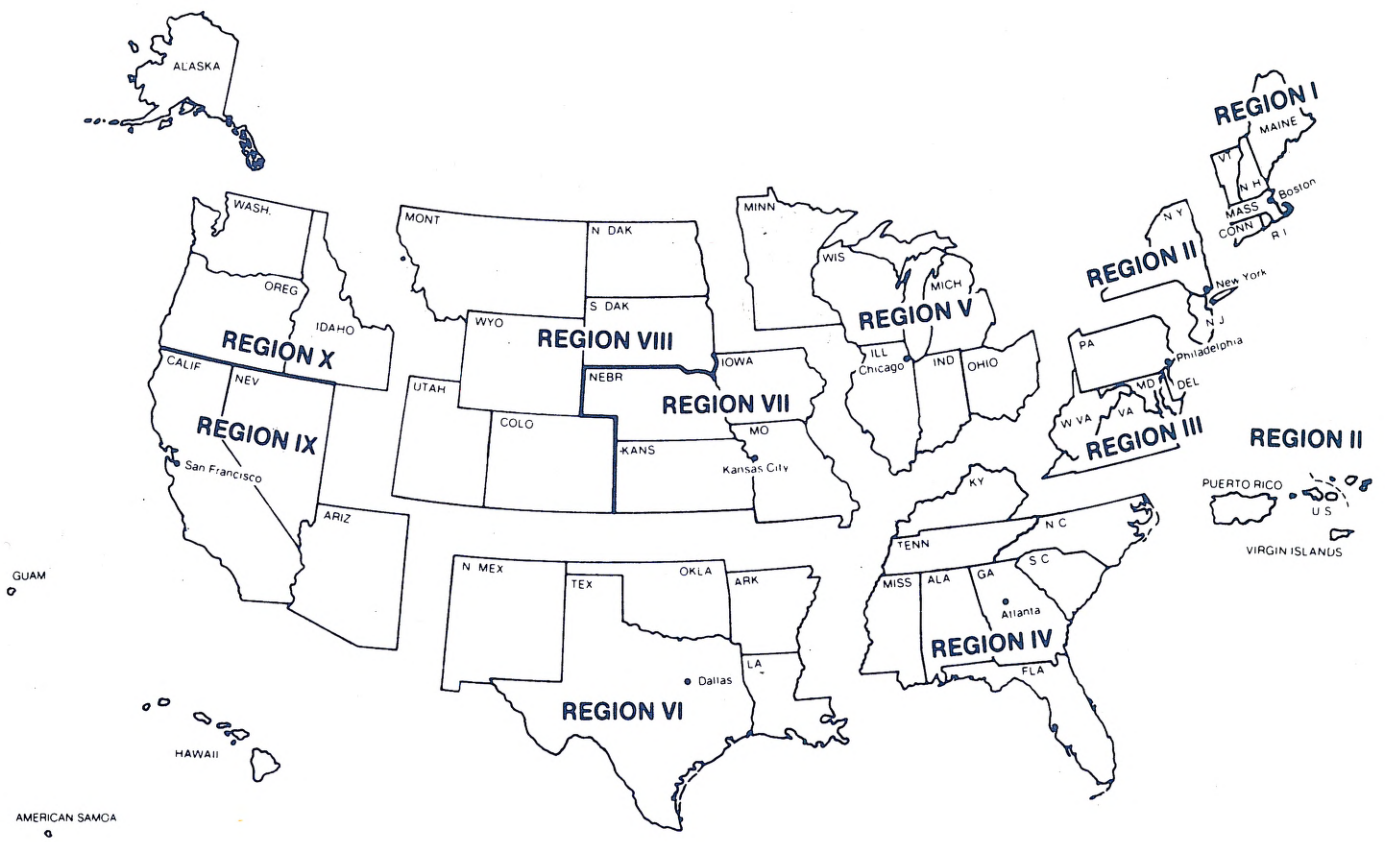

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