Trends in Output per Man-Hour in the Private Economy, 1909-1958

Bulletin No. 1249

UNITED STATES DEPARTMENT OF LABOR
James P. Mitchell, Secretary

BUREAU OF LABOR STATISTICS
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PREFACE

The efficient use of labor and other resources in the production of a Nation's goods and services has long been recognized as the means to higher levels of economic well-being and national strength. This resource use and its consequences enter into almost every facet of economic activity, including industrial development, price stability, economic growth, manpower utilization, costs of the factors of production, and international competition.

The Bureau of Labor Statistics has in the past prepared measures of output per man-hour for selected industries and for major sectors of the economy, such as agriculture, mining, and manufacturing. These measures have been useful in providing data on trends in the specific areas they cover but have provided only partial coverage of the economy.

In order to provide broader measures on a continuing basis, the Bureau has developed the estimates of output per man-hour in the private economy for the post-World War II period which are presented in this report. Estimates based on other sources, covering the period prior to 1947, are also presented.

In addition to series covering the entire private economy, data are also presented for the farm and nonfarm sectors separately, and for the manufacturing and nonmanufacturing groups within the latter sector. Two sets of measures have been prepared based on different man-hour sources--Bureau of Labor Statistics and Bureau of Census labor force data.

This study was prepared in the Bureau's Division of Productivity and Technological Developments under the general direction of Leon Greenberg, Chief, and Jack Alterman, Assistant Chief of the Division, and under the direct supervision of Jerome A. Mark, Chief of the Branch of Special Studies. Elizabeth Kahn assisted in the development of the output per man-hour measures and prepared portions of the appendix text relating to the man-hour measures. Eva E. Jacobs prepared portions of the appendix text relating to the real product measures.

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TRENDS IN OUTPUT PER MAN-HOUR IN THE PRIVATE ECONOMY, 1909-58

Introduction

Output per man-hour, of vital importance to the Nation's economic strength, has been the object of continuing widespread attention. However, the focus of this attention has varied from time to time, depending upon economic conditions. During periods of depression and recession, emphasis has been placed on the relationship of output per man-hour to employment and unemployment. During inflationary periods, primary interest has centered on the problem of offsetting rising costs and thus promoting price stability.

In this report, output per man-hour refers specifically to the constant dollar value of goods and services produced in relation to the hours of all persons employed (including proprietors and unpaid family workers), and is designated in the accompanying tables as "real product per man-hour." This kind of measure is relevant to problems of manpower utilization, employment, unemployment, labor costs, levels of living, and other elements in economic growth.

Although the measure relates output to man-hours, it should not be interpreted to represent the unique contribution of labor to production. Rather the measure reflects, in addition to labor effort and skill, the operation of many factors, such as changes in technology, equipment, and other capital investment per worker, utilization of capacity, layout and flow of materials, managerial skill, and labor-management relations. Thus, gains in output per man-hour cannot be ascribed to any one factor, but reflect the interaction of all factors.

This report presents indexes and average rates of change in output per man-hour for the private economy, agriculture, and nonagriculture for the post-World War II period, 1947-58, and for the long-term period 1909-58. 1/ Estimates are also presented for manufacturing and nonmanufacturing for the period 1947-57.

The indexes of output per man-hour are derived from estimates of real product and of man-hours. The real product estimates represent, as indicated earlier, the constant dollar value of goods and services produced in the

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1/ At present there is no satisfactory method of measuring many of the goods and services produced by the government sector of the economy which is excluded from these indexes. However, for purposes of this study, government enterprises, such as the Post Office, TVA, and local transit systems, whose major activities involve the sale of a product or service, are combined with the private sector.

private economy. They include the unduplicated value of the successive stages of extraction, processing, and distribution. Data on real product for the total private economy and the agricultural and nonagricultural sectors are compiled by the U.S. Department of Commerce, Office of Business Economics; for manufacturing, the estimates of real product have been developed by the U.S. Department of Labor, Bureau of Labor Statistics, based on data from the Bureau of the Census and other sources.

Since there are two major sources of data on employment and weekly hours which can be used to derive a measure of man-hours for the total economy, two sets of estimates have been developed for this report--one based on data from the Bureau of the Census, 2/ the other based primarily on data from the Bureau of Labor Statistics, supplemented by other sources.

In concept, the estimates based on Bureau of the Census labor force data are defined as output per hour worked. The labor force measure, however, does not attempt to exclude all nonworked hours such as rest periods and standby time. The estimates based primarily on BLS data are defined as output per hour paid, but they do not include such time as sick leave compensated for under insurance programs. Theoretically, the differences between the two measures, as used in this study, represent the change in the proportion of hours for paid vacations and paid sick leave to total paid hours.

Actual differences between these two sets of measures are the result of differences in statistical methodology and reporting as well as differences in concept. For example, the estimates based on the Census data are from sample surveys of households, whereas the BLS data are obtained from reports of establishments.

The man-hours are the sum of man-hours worked (or paid) of all persons engaged in the various sectors of the private economy. No distinction is made between groups with different levels of skill or rates of pay.

In evaluating and using the output per man-hour measures given in this report, certain qualifications should be kept in mind. 3/ First, the output and man-hour data provide only partial coverage for some industries or categories, thus requiring imputations of one sort or another. Second, existing data and techniques do not fully account for changes in quality of goods and

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2/ As of July 1959 the responsibility for the labor force estimates was transferred from the Bureau of the Census to the Bureau of Labor Statistics, although the Bureau of the Census continues to collect the basic data.

3/ The qualifications and limitations are discussed more fully in the appendix. See pp. A-34-36.

services produced. Third, there are problems of maintaining consistency between methods of estimating output and labor input as well as between the output per man-hour measures and other economic variables. Fourth, the choice of a particular base year for the weights may have an effect on the trend. Fifth, there is considerable variation in trends of individual component factors and industries, many differing from the sector trend and the trend for the private economy. Sixth, year-to-year changes in output per man-hour are irregular and, therefore, not necessarily indicative of long-term trends; similarly, long-term trends are not necessarily applicable to any one year, to any particular group of years, or to any period in the future.

Because of the statistical limitations, the measures cannot be considered to have the accuracy of precision instruments. Instead, they should be considered as general indicators of productivity movements and should be used as such.

TRENDS IN REAL PRODUCT PER MAN-HOUR

Introduction

Over the long run, underlying technological and institutional factors tend to provide the basis for cumulative increases in output per man-hour. Changes in output per man-hour, however, may also be heavily influenced by conditions of war or peace, recession or prosperity. They may be affected by such factors as changes in volume of production, utilization of capacity, and shifts in the labor force or output from one part of the economy to another.

This section describes the trends in output per man-hour for the private economy and its major components, agriculture and nonagriculture. Major emphasis is on the postwar period 1947-58, for which the estimates were developed by the Bureau of Labor Statistics. (The year 1947 is the first postwar year for many other economic time series.) Long-term trends, based on estimates from other sources for the period 1909-47, are also presented for purposes of comparison.

The average rates of change are intended to describe the nature of growth in output per man-hour for past periods. The factors already mentioned, plus others which have affected past rates of change, can also be expected to have a varying influence on future productivity growth.

Postwar Period, 1947-58

Total Private Economy. Total private real product per man-hour increased 35 percent based on Bureau of Labor Statistics man-hours, 39 percent based on Census man-hours from the base period 1947-49 to 1958 (tables 1 and 2). The average annual increases for the entire period 1947-58 were 3.1 and 3.5 percent, respectively (table 3).

It is to be expected that output per man-hour measures based on hours paid would increase less than those based on hours worked, because of increases in paid vacations and sick leave. However, some of the differences between the two measures are due to reporting, estimating, and other statistical factors.

4/ The real product (output) part of the estimates is private gross national product in 1954 prices.

5/ The averages are computed from the least squares trend of the logarithms of the index numbers. In contrast to the compound interest rate, which takes into account only the terminal years, the least squares procedure accounts for all the year-to-year changes during the period covered, 1947-58.

Table 1. Indexes of employment, man-hours, real product, real product per man-hour and hours paid per dollar of real product, 1947-58

(Man-hour estimates based primarily on Bureau of Labor Statistics data)
(1947-49=100)

	Item	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
	Employment:												
1.	Total private	99.9	101.1	99.0	100.9	104.5	105.6	107.1	104.4	108.5	111.3	111.0	107.1
2.	Agriculture	101.7	98.6	99.7	93.8	88.5	85.4	78.6	77.8	80.5	78.8	74.6	70.0
3.	Nonagricultural industries	99.5	101.6	98.9	102.1	107.4	109.2	112.2	109.2	113.5	117.1	117.6	113.7
4.	Manufacturing	102.4	102.6	95.0	100.3	107.9	109.4	115.4	107.1	110.8	113.1	112.2	103.5
5.	Nonmanufacturing	98.2	101.1	100.7	103.0	107.2	109.1	110.7	110.2	114.8	119.1	120.1	118.5
	Average weekly hours:												
6.	Total private	100.9	100.2	99.1	99.1	98.8	98.6	98.1	97.2	97.6	96.9	95.5	94.8
7.	Agriculture	101.0	100.4	98.6	97.2	98.2	97.2	98.4	96.6	95.2	93.2	91.0	90.2
8.	Nonagricultural industries	100.7	100.2	99.0	99.5	99.5	99.5	98.8	98.1	98.8	98.3	97.3	96.4
9.	Manufacturing	101.0	100.5	98.8	101.2	101.5	101.8	101.2	99.8	101.5	101.0	99.8	98.8
10.	Nonmanufacturing	100.7	100.0	99.0	98.6	98.3	98.3	97.8	97.4	97.4	97.1	96.2	95.2
	Annual hours:												
11.	Total private	100.8	101.3	97.9	99.8	103.3	104.1	104.9	101.4	105.8	107.8	106.1	101.4
12.	Agriculture	102.7	99.0	98.3	91.2	86.9	83.0	77.3	75.2	76.6	73.4	67.9	63.2
13.	Nonagricultural industries	100.4	101.8	97.8	101.6	106.8	108.6	110.9	107.1	112.1	115.2	114.4	109.7
14.	Manufacturing	103.4	102.9	93.6	101.5	109.5	111.1	116.7	106.6	112.5	114.1	112.0	102.1
15.	Nonmanufacturing	98.9	101.3	99.7	101.7	105.6	107.5	108.3	107.3	111.9	115.8	115.5	113.1
	Gross national product:												
16.	Total private	97.5	101.5	100.9	110.2	116.9	120.4	126.3	124.3	135.4	138.3	140.9	137.3
17.	Agriculture	92.9	106.0	100.5	106.0	99.5	103.3	107.1	111.5	117.6	114.8	113.2	119.2
18.	Nonagricultural industries	97.9	101.2	101.0	110.5	118.1	121.6	127.7	125.2	136.7	140.0	142.9	138.6
19.	Manufacturing	100.9	103.0	96.0	111.1	121.8	125.5	138.1	125.1	141.3	145.0	143.0	(1/)
20.	Nonmanufacturing	96.2	100.2	103.6	110.2	116.2	119.6	122.2	125.2	134.3	137.4	143.0	(1/)
	Real product per man-hour:												
21.	Total private	96.7	100.2	103.1	110.4	113.2	115.7	120.4	122.6	128.0	128.3	132.8	135.4
22.	Agriculture	90.5	107.1	102.2	116.2	114.5	124.5	138.6	148.3	153.5	156.4	166.7	188.6
23.	Nonagricultural industries	97.5	99.4	103.3	108.8	110.6	112.0	115.1	116.9	121.9	121.5	124.9	126.3
24.	Manufacturing	97.6	100.1	102.6	109.5	111.2	113.0	118.3	117.4	125.6	127.1	127.7	(1/)
25.	Nonmanufacturing	97.3	98.9	103.9	108.4	110.0	111.3	112.8	116.7	120.0	118.7	123.8	(1/)
	Hours paid per dollar of real product:												
26.	Total private	103.4	99.8	97.0	90.6	88.4	86.5	83.1	81.6	78.1	77.9	75.3	73.9
27.	Agriculture	110.5	93.4	97.8	86.0	87.3	80.3	72.2	67.4	65.1	63.9	60.0	53.0
28.	Nonagricultural industries	102.6	100.6	96.8	91.9	90.4	89.3	86.8	85.5	82.0	82.3	80.1	79.1
29.	Manufacturing	102.5	99.9	97.5	91.4	89.9	88.5	84.5	85.2	79.6	78.7	78.3	(1/)
30.	Nonmanufacturing	102.8	101.1	96.2	92.3	90.9	89.9	88.6	85.7	83.3	84.3	80.8	(1/)

1/ Not available.

Source: Table A-1, (p. A-19).

Table 2. Indexes of labor force, employment, man-hours, real product per man-hour and hours worked per dollar of real product, 1947-58

(Man-hour estimates based primarily on Bureau of the Census Labor Force data)
(1947-49=100)

	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1. Total labor force	98.3	100.2	101.5	103.2	105.2	106.1	106.8	107.5	109.3	111.6	112.2	113.0
2. Armed Forces	102.3	93.7	104.0	106.2	199.4	231.3	228.2	215.6	196.1	183.8	180.0	169.7
3. Civilian labor force	98.2	100.3	101.5	103.1	102.8	102.9	103.8	104.8	107.1	109.8	110.5	111.6
4. Unemployed	84.5	83.4	132.1	120.2	75.3	69.3	67.1	128.3	104.2	101.2	105.3	167.9
5. Employed	98.9	101.1	100.0	102.3	104.1	104.5	105.5	103.7	107.2	110.2	110.7	108.9
6. Government civilian-general	96.6	99.9	103.5	106.5	113.8	117.6	118.6	120.3	125.0	130.7	135.0	139.7
7. Total private	99.1	101.3	99.7	101.9	103.2	103.3	104.2	102.1	105.5	108.2	108.4	106.0
8. Agriculture	101.7	98.6	99.7	93.8	88.5	85.4	78.6	77.8	80.5	78.8	74.6	70.0
9. Nonagricultural industries	98.6	101.7	99.7	103.4	105.9	106.6	109.0	106.6	110.1	113.7	114.6	112.6
Average weekly hours:												
10. Total private	101.0	100.1	98.9	97.9	98.4	98.2	97.7	95.8	96.5	95.5	94.3	93.2
11. Agriculture	100.7	100.1	99.2	97.4	98.6	97.4	98.8	97.0	95.5	93.5	91.0	90.0
12. Nonagricultural industries	100.9	100.2	98.9	98.4	98.9	98.7	98.4	96.5	97.5	96.7	95.7	94.5
Annual hours:												
13. Total private	100.1	101.2	98.7	99.9	101.5	101.3	101.9	97.9	101.7	103.5	102.2	98.7
14. Agriculture	102.5	98.6	98.9	91.3	87.2	83.3	77.6	75.4	76.9	73.7	67.8	63.0
15. Nonagricultural industries	99.5	101.8	98.6	101.8	104.7	105.3	107.3	102.8	107.2	110.1	109.8	106.5
Gross national product (1954 dollars):												
16. Total private	97.5	101.5	100.9	110.2	116.9	120.4	126.3	124.3	135.4	138.3	140.9	137.3
17. Agriculture	92.9	106.0	100.5	106.0	99.5	103.3	107.1	111.5	117.6	114.8	113.2	119.2
18. Nonagricultural industries	97.9	101.2	101.0	110.5	118.1	121.6	127.7	125.2	136.7	140.0	142.9	138.6
Real product per man-hour:												
19. Total private	97.4	100.3	102.2	110.3	115.2	118.9	123.9	127.0	133.1	133.6	137.9	139.1
20. Agriculture	90.6	107.5	101.6	116.1	114.1	124.0	138.0	147.9	152.9	155.8	167.0	189.2
21. Nonagricultural industries	98.4	99.4	102.4	108.5	112.8	115.5	119.0	121.8	127.5	127.2	130.1	130.1
Hours worked per dollar of real product:												
22. Total private	102.7	99.7	97.8	90.7	86.8	84.1	80.7	78.8	75.1	74.8	72.5	71.9
23. Agriculture	110.3	93.0	98.4	86.1	87.6	80.6	72.5	67.6	65.4	64.2	59.9	52.9
24. Nonagricultural industries	101.6	100.6	97.6	92.1	88.7	86.6	84.0	82.1	78.4	78.6	76.8	76.8

Source: Table A-2, (p. A-22)

Table 3. Average annual percent change in real product per man-hour for the postwar period 1/

Sector and period	Average annual percent change	
	Based primarily on man-hour data from--	
	BLS 2/	Census 3/
1947-58:		
Total private	3.1	3.5
Agriculture 4/	6.2	6.2
Nonagriculture	2.4	2.9
1947-57:		
Nonagriculture	2.5	--
Manufacturing	2.9	--
Nonmanufacturing	2.3	--

1/ Computed from the least squares trend of the logarithms of the index numbers. Covers man-hours of wage and salary workers, self-employed, and unpaid family workers. Annual indexes of real product per man-hour and related data are given in tables 1 and 2. Differences between measures based on BLS and Census man-hour data reflect differences in concept (hours paid versus hours worked) and statistical differences.

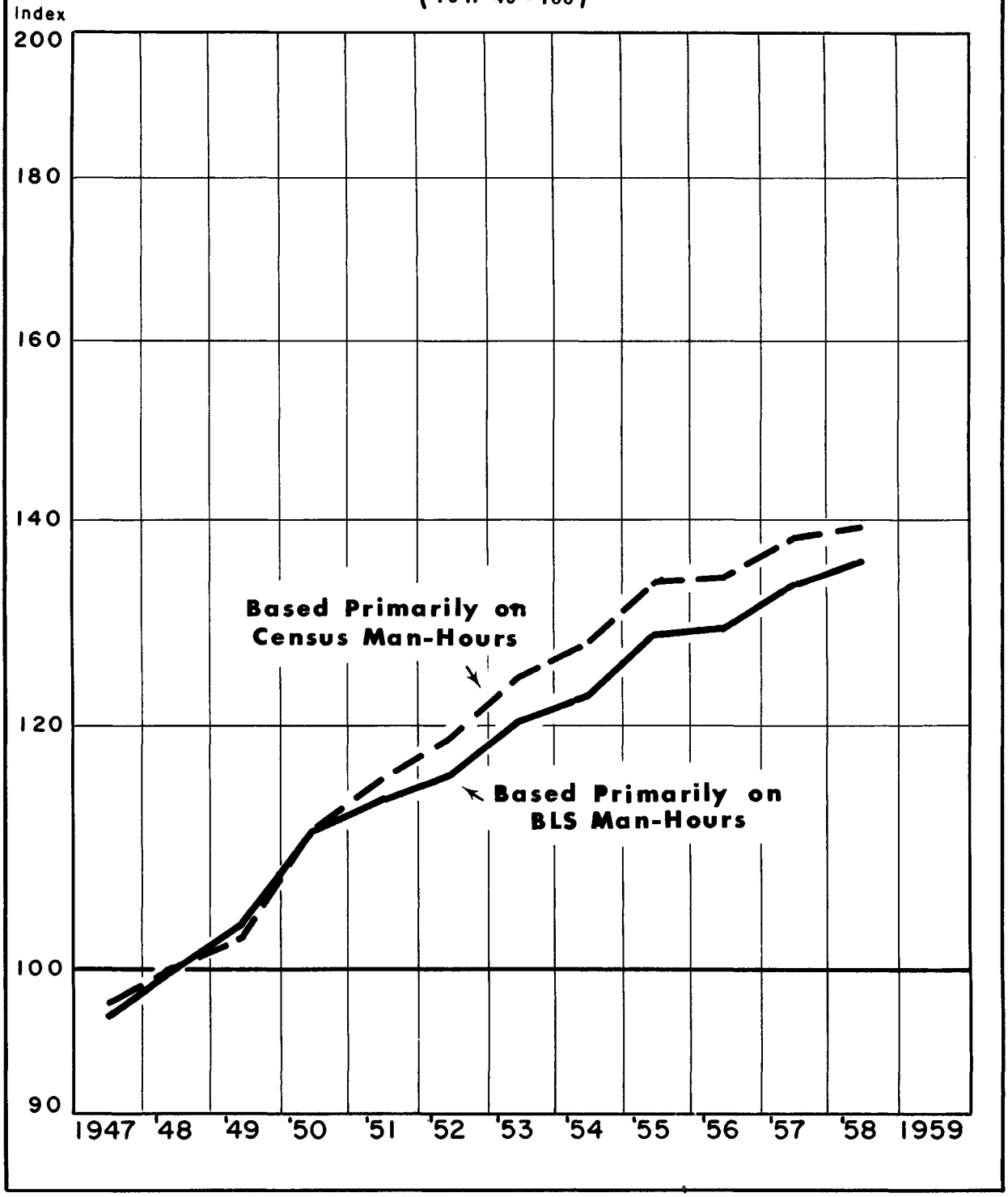
2/ Estimate based primarily on Bureau of Labor Statistics data supplemented by data from other sources. Includes hours of unpaid family workers.

3/ Estimate based primarily on Census labor force data supplemented by data from other sources.

4/ Estimate based on Census labor force data on agricultural employment and hours. Not comparable with agricultural productivity measures based on the Department of Agriculture's man-hour measures of equivalent adult male labor requirements.

Chart 1. Indexes of Real Product Per Man-Hour in the Total Private Economy, 1947-58

(1947-49 = 100)



Annual changes in output per man-hour during the period, ranging from practically zero to nearly 8 percent, were affected by varying economic conditions, with larger-than-average gains occurring during periods of economic expansion and smaller-than-average gains occurring during periods of stable or declining economic activity. For example, the largest single gain occurred in 1950, a year when there was a large gain in gross national product. Smaller-than-average gains occurred in 1949, 1954, and 1958, years of economic downturn. In 1956, although there was a moderate increase in constant dollar private gross national product, economic activity was already at a high level and output per man-hour showed little increase.

The indexes for the postwar period illustrate the point that year-to-year changes are not evenly distributed over time and that a substantial productivity gain for 1 or 2 years does not necessarily forecast substantial future gains, nor does lack of much gain imply a stagnation in future growth.

Major Sectors. The change in output per man-hour for the total private economy is, of course, a function of the changes in its component sectors such as agriculture, manufacturing, and nonmanufacturing.

The outstanding characteristic of the postwar period was the striking performance of agriculture, which accounted for 10 percent of total private employment and 6-1/2 percent of total output in 1958 (table A-1). Output per man-hour in this sector nearly doubled from its 1947-49 average to 1958, reflecting the improved application of farm machinery, insecticides, fertilizer, and seed. During this period, agricultural output increased about 19 percent, while aggregate hours decreased 37 percent (tables 1 and 2). The decline in hours was largely the result of a drop in farm employment. The average annual increase in output per man-hour was 6.2 percent for the period 1947-58 (table 3).

For nonagricultural industries, the gain in output per man-hour from the 1947-49 average to 1958 was 26 percent based on BLS hours, 30 percent based on Census hours. In this sector, output increased by about 39 percent while aggregate man-hours increased by less than 10 percent, based on the BLS measure and by less than 7 percent on the Census measures (tables 1 and 2). The average annual rates were 2.4 and 2.9 percent, respectively for the 1947-58 period (table 3).

Manufacturing output per man-hour, based primarily on BLS hours for all persons employed in manufacturing, rose about 2.9 percent a year from 1947 to 1957 (table 3). 6/

6/ 1958 estimates for manufacturing are not yet available.

Chart 2. Indexes of Real Product Per Man-Hour in the Total Private Economy, Agricultural, Nonagricultural, Manufacturing, and Nonmanufacturing Sectors, 1947-58

Based Primarily on BLS Man-Hour Data

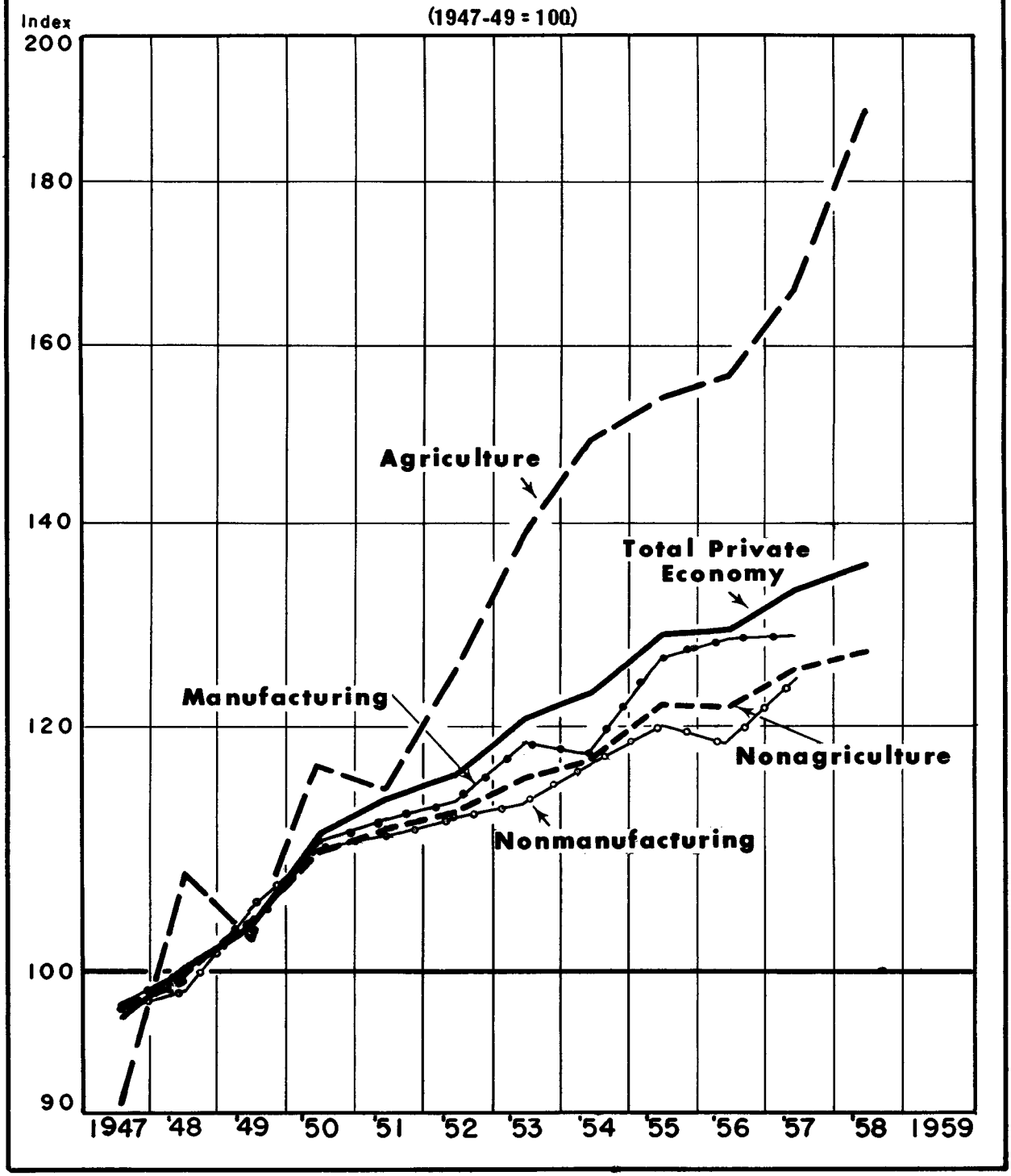
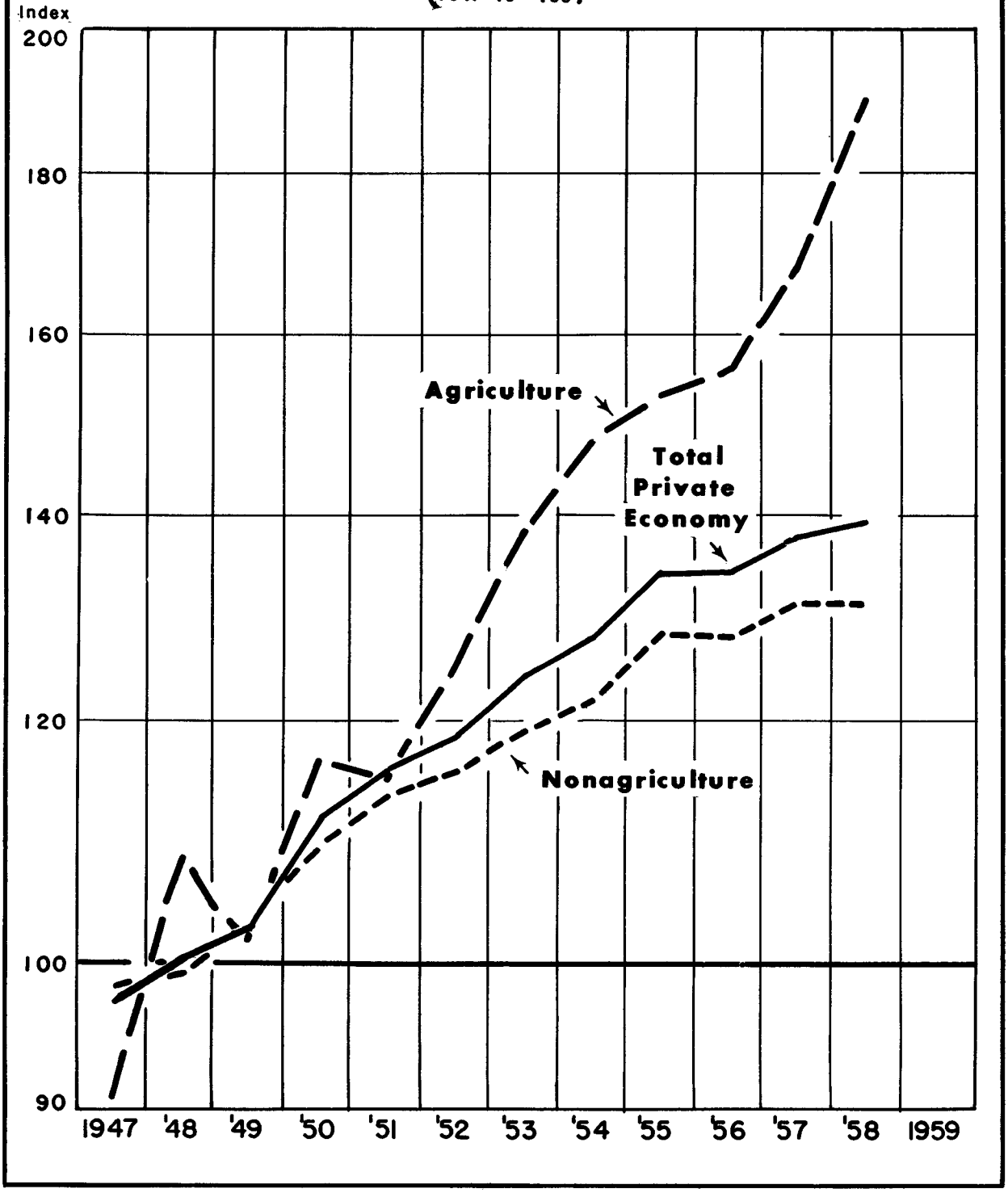


Chart 3. Indexes of Real Product Per Man-Hour in the Total Private Economy, Agricultural, and Nonagricultural Sectors, 1947-58

Based on Census Man-Hour Data

(1947-49 = 100)



Most previously published estimates of manufacturing output per man-hour have dealt with output per man-hour of production workers. Because of the continuing interest in the employment and average hours and earnings of production workers, more data are available for this group than for nonproduction workers. 7/ The average annual increase for production worker output per man-hour in manufacturing (1947-57) was about 3.7 percent a year, nearly 1 percent higher than that for all persons employed in manufacturing. This difference, which is growing, arises because of the greater increase in employment of nonproduction workers in relation to production workers. (See section on Factors Affecting Output per Man-Hour.)

In the nonmanufacturing industries, output per man-hour of all persons, based primarily on BLS hours, rose about 24 percent from the 1947-49 average to 1957. The average annual increase was 2.3 percent for the period 1947-57. This rate of increase is somewhat less than that for manufacturing. However, the nonmanufacturing sector represents a heterogeneous group of industries including mining, transportation, construction, and public utilities, as well as trade and services. Several research studies indicate that some of these have experienced substantial output per man-hour gains, 8/ while others have shown very little change.

Shifts Between Sectors

Overall changes in output per man-hour reflect both changes in output per man-hour of component sectors, industries, etc., and changes (shifts) in the relative importance of components with different levels of output per man-hour. Shifts can reflect either changes in the labor force "mix" or changes in the product "mix." For example, the shift of manpower from the agricultural sector to the nonagricultural sectors has the following effect: For every given man-hour, a greater value of output can be produced in nonagriculture than in agriculture. Therefore, if man-hours are shifted from agriculture to nonagriculture, the total value of output will increase, thus yielding a gain in output per man-hour. In the case of the output shift, for every given dollar of output fewer man-hours are required in the nonagricultural sector than in the agricultural sector. Therefore, if output is shifted from agriculture to nonagriculture, there is a decrease in the man-hours required per unit of total output, which is equivalent to an increase in output per man-hour. It should also be noted that output per man-hour of individual industries and sectors can also be affected by shifts of marginal workers or productive units into or out of the sector or industry, e.g., effect of the reduction in marginal farms on output per man-hour of the agricultural sector.

7/ For definitions of production and nonproduction workers, see p. 39.

8/ See Estimates of Real Product in the United States by Industrial Sector, 1947-55, by Jack Alterman and Eva Jacobs, presented at the Conference on Research in Income and Wealth, New York, N. Y., October 1958.

Shifts can occur at all levels in the economy, including occupations, products, plants, industries, industry groups, and major sectors. In order to examine the movements of output per man-hour excluding the effect of shifts, the procedure employed is to hold constant the output or man-hours of these components, as of a particular year, such as 1947 or 1958. However, the extent to which the effect of the various categories of shifts can be excluded from the overall measure of output per man-hour is limited by the availability of data.

Estimates have been developed for the postwar period excluding the effect of shifts between the agricultural and total nonagricultural sectors on output per man-hour of the total private economy. These estimates indicate that, for the postwar period, elimination of output shifts between agriculture and nonagriculture reduces the average annual change of output per man-hour by a small amount--from 3.5 percent to 3.4 percent for the Census-based measure. Elimination of the man-hour shift has a greater effect, reducing the average annual change from 3.5 to about 3.0 percent. 9/ The corresponding measures based on BLS man-hours followed a similar pattern (table 4).

Table 4. Average annual change in real product per man-hour with sector proportions constant, 1947-58 1/

	Average annual percent change	
	Based primarily on man-hour data from--	
	BLS	Census
Agricultural-nonagricultural proportions constant; with:		
1947 output proportions ...	3.0	3.4
1958 output proportions ...	2.9	3.4
1947 man-hour proportions .	2.7	3.1
1958 man-hour proportions .	2.6	3.0

1/ Output per man-hour indexes for the sectors are combined with constant weights (man-hours or output, 1947 or 1958). This removes the effect of shifts in the relative importance of man-hours or output between 1947 and 1958.

9/ These changes are approximately the same whether 1947 or 1958 proportions are used.

In addition, estimates developed to show the further effect of eliminating shifts between total manufacturing and nonmanufacturing sectors indicate that these shifts apparently have had very little influence on the rate of change in output per man-hour for the postwar period. This does not take account of the possible effect of further shifts between and within industries in manufacturing and nonmanufacturing. Some research work indicates that the effect of part of the shifts within nonmanufacturing is negative, i.e., reduces the overall level of output per man-hour. 10/ However, these are only partial measures and the net effect of all the interindustry shifts has not yet been measured.

10/ See Jack Alterman and Eva Jacobs, op. cit.

Long-Term Period

Introduction. Public interest in the United States in recent years has become focused on the long-run trend of economic growth. Questions are raised as to whether the period since World War II is typical of former periods and whether there are any signs that the rate of growth is increasing.

Economic growth is partly determined by the expansion of the labor force and other related factors, but the dominant factor in a dynamic economy is the rate of gain in output per man-hour. Analysis of the long-term trends in output per man-hour is therefore essential to analysis of the long-term trends in economic growth.

At the outset, a clear and sharp distinction must be drawn between the basic data on output per man-hour presented in this report and the trend calculations derived from them. Trends are derived in order to discover whether there are any underlying movements which are concealed or lost in the variations of the data from year to year.

Trend measures, however, are influenced by various factors in addition to the basic data. For example, the trend calculation may vary according to periods selected for measurement. Calculation of trends for various short-term periods frequently shows different results from one measured over the long term. Similarly, the selection of the terminal years of the long-term period itself may affect the result. The form of statistical description also affects the trend measure. This description can range from the simple to the complex--for example, from a simple comparison of the first and last year of a series to more complicated mathematical derivations of least squares lines or curves fitted to the data over a period of years. The particular formulation chosen affects the measure of trend and the conclusions drawn from this measure.

There are also economic factors which can influence the measure of trend in output per man-hour in the economy. These include changes which occur in the various sectors and industries, shifts in the relative importance of the sectors, and changes in the degree of capacity utilization which occur in the economy.

In all of these, it should be noted that some judgment enters into the statistical analysis. There is no one best trend for most series. The approach applied depends on the aspect of growth which is being examined. To illustrate: For some purposes, it is desirable to derive a measure of trend which excludes the effect of shifts in component sectors or industries; for other purposes, it is essential that the trend measure include the effect of these shifts.

Any measure of trend reflects only the average events of the past. It cannot be properly extended into the future without careful judgment and analysis of pertinent economic conditions--of the past, present, and future. Since

trends reflect the influence of so many variables, extrapolations of long-term movements must be qualified by assumptions of the degree of capacity utilization, manpower availability, changes in product and industry mix, the trends of individual sectors, and general economic conditions.

Total Private Economy

Output per man-hour for the private economy nearly tripled between 1909 and 1958. 11/ This was equivalent to an average annual increase of 2.3 to 2.4 percent per year based on the usual (straight-line) method of calculating average rates of change (table 6). This method ascribes a constant annual rate of increase to the 50-year period, although the actual changes in many years were considerably higher or lower.

The course which output per man-hour followed to achieve this growth was not smooth, exhibiting annual, cyclical, and irregular fluctuations (table 5 and chart 4). At various times, deep troughs occurred, such as those in 1917, 1933, and 1946; at other times, peaks appeared; and for most of the remaining time, more or less sustained growth took place. In some cases, these movements corresponded with other major developments of the past half century, e.g., two major wars, a major depression and several recessions--but in other cases, they did not.

There appear to have been roughly three cycles in the movement of output per man-hour from 1909 to 1958. Although the dividing points of the cycles are by no means clear, they seem to have started with the three troughs mentioned above. While the depth of the trough and the duration and speed of recovery varied considerably for each cycle period, the average increase in output per man-hour for the first decade in each cycle exceeded that for the entire 50-year span.

These cycles were not comparable in terms of economic conditions. It is probably more meaningful to compare the post-World War II period, 1947-58, with the corresponding post-World War I period, 1920-30, 12/ although here, too, the conditions were not identical (e.g., the first period did not require mobilization similar to that of the more recent Korean conflict). In the decade

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11/ This analysis begins with 1909. This is the first year for which official constant dollar estimates of national product are available. See U.S. Income and Output, Supplement to Survey of Current Business, November 1958. Office of Business Economics, U.S. Department of Commerce, table I-16.

12/ The beginning year in each case, 1920 and 1947, represents the second full year following the end of the war. The terminal years 1930 and 1958 were years of recession. The employment-labor force ratios were quite similar for the comparable terminal years. (See section on Relationship of Trend to Capacity Utilization, p. 28, for explanation of this ratio.)

Table 5. Real product per man-hour in the private economy, agricultural and nonagricultural sectors, 1909-58

(1947-49=100)

Year	BLS 1/			Census 2/		
	Total private	Agri-culture	Nonagri-culture	Total Private	Agri culture	Nonagri culture
1909. . .	47.6	58.2	51.6	47.8	58.6	52.0
1910. . .	47.6	59.2	51.1	47.7	59.4	51.4
1911. . .	47.9	55.9	51.8	48.0	56.2	52.2
1912. . .	49.2	62.8	52.3	49.5	63.2	52.7
1913. . .	49.3	57.1	53.0	49.5	57.3	53.4
1914. . .	47.7	59.8	51.4	48.0	60.2	51.8
1915. . .	47.8	64.7	50.6	47.9	65.1	50.9
1916. . .	48.2	59.4	50.9	48.5	59.6	51.3
1917. . .	46.7	61.6	48.9	46.9	61.9	49.2
1918. . .	48.7	59.0	51.8	48.9	59.4	52.2
1919. . .	52.4	60.4	56.3	52.5	60.8	56.7
1920. . .	49.9	59.0	53.6	50.2	59.4	54.0
1921. . .	50.5	58.1	54.8	50.7	58.4	55.1
1922. . .	55.2	60.6	59.7	55.4	61.0	60.2
1923. . .	57.8	63.5	61.3	58.1	63.9	61.8
1924. . .	58.9	60.4	63.6	59.2	60.8	64.2
1925. . .	61.9	63.1	66.7	62.1	63.5	67.2
1926. . .	63.3	61.4	68.1	63.5	61.7	68.5
1927. . .	63.5	66.8	67.3	63.8	67.1	67.7
1928. . .	63.3	63.0	67.5	63.7	63.5	68.0
1929. . .	65.8	66.9	69.8	66.2	67.4	70.2
1930. . .	63.2	61.9	68.1	63.5	62.3	68.6
1931. . .	63.5	70.6	69.2	63.7	70.8	69.7
1932. . .	60.1	68.9	66.7	60.3	69.5	67.2
1933. . .	58.5	68.0	64.8	58.6	68.2	65.4
1934. . .	64.8	62.7	72.0	65.3	63.1	72.6
1935. . .	68.3	73.7	74.5	68.6	74.2	75.0
1936. . .	71.9	64.7	78.1	72.2	65.1	78.7
1937. . .	72.5	75.0	77.9	72.9	75.3	78.5
1938. . .	74.7	81.3	79.9	75.0	81.6	80.5
1939. . .	77.6	81.0	82.6	78.0	81.2	83.2
1940. . .	81.3	80.3	86.1	81.8	80.8	86.8
1941. . .	85.9	87.9	88.9	86.5	88.6	89.5
1942. . .	86.7	91.8	88.9	87.3	92.4	89.6
1943. . .	88.0	85.6	90.2	88.5	85.8	90.7
1944. . .	94.0	88.1	96.7	94.7	88.7	97.4

See footnotes at end of table.

Table 5. Real product per man-hour in the private economy, agricultural and nonagricultural sectors, 1909-58--Continued

(1947-49=100)

Year	BLS 1/			Census 2/		
	Total private	Agri-culture	Nonagri-culture	Total private	Agri-culture	Nonagri-culture
1945. . .	98.5	89.2	101.3	99.0	89.3	101.9
1946. . .	96.0	93.8	97.5	96.6	94.4	98.2
1947. . .	96.7	90.5	97.5	97.4	90.6	98.4
1948. . .	100.2	107.1	99.4	100.3	107.5	99.4
1949. . .	103.1	102.2	103.3	102.2	101.6	102.4
1950. . .	110.4	116.2	108.8	110.3	116.1	108.5
1951. . .	113.2	114.5	110.6	115.2	114.1	112.8
1952. . .	115.7	124.5	112.0	118.9	124.0	115.5
1953. . .	120.4	138.6	115.1	123.9	138.0	119.0
1954. . .	122.6	148.3	116.9	127.0	147.9	121.8
1955. . .	128.0	153.5	121.9	133.1	152.9	127.5
1956. . .	128.3	156.4	121.5	133.6	155.8	127.2
1957. . .	132.8	166.7	124.9	137.9	167.0	130.1
1958. . .	135.4	188.6	126.3	139.1	189.2	130.1

1/ Output per man-hour series based on real product data from the Office of Business Economics, U.S. Department of Commerce, and unpublished man-hours data prepared by John W. Kendrick linked in 1947 to BLS man-hours.

2/ Output per man-hour series based on real product data from the Office of Business Economics, U.S. Department of Commerce, and unpublished man-hours data prepared by John W. Kendrick linked in 1947 to Census man-hours.

Chart 4. Indexes of Real Product Per Man-Hour in the Total Private Economy, Agriculture, and Nonagriculture, 1909-58

Post-World War II Period Based Primarily on BLS Man-Hours

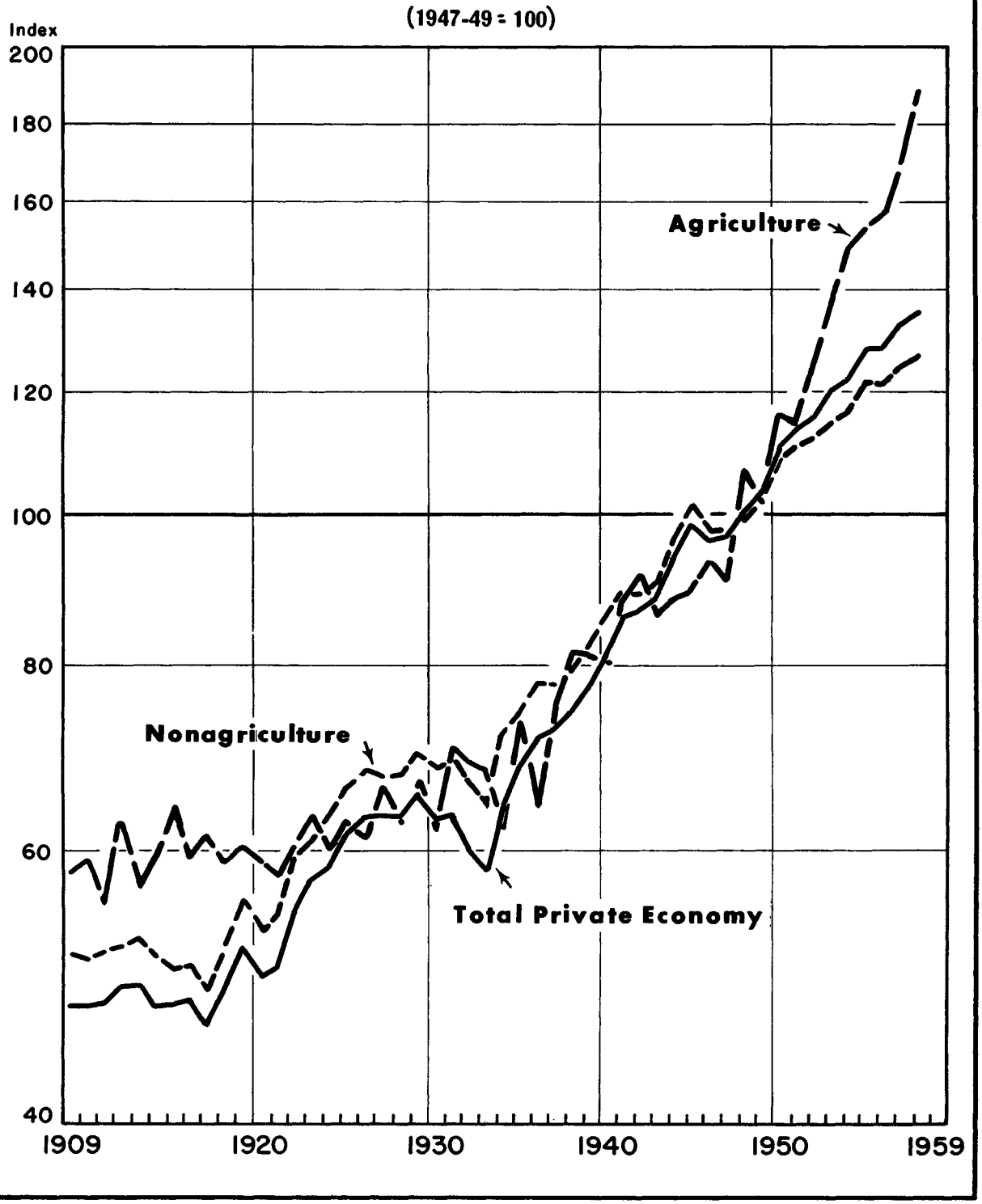

Chart 5. Indexes of Real Product Per Man-Hour in the Total Private Economy, Agriculture, and Nonagriculture, 1909-58

Post-World War II Period Based Primarily on Census Man-Hours

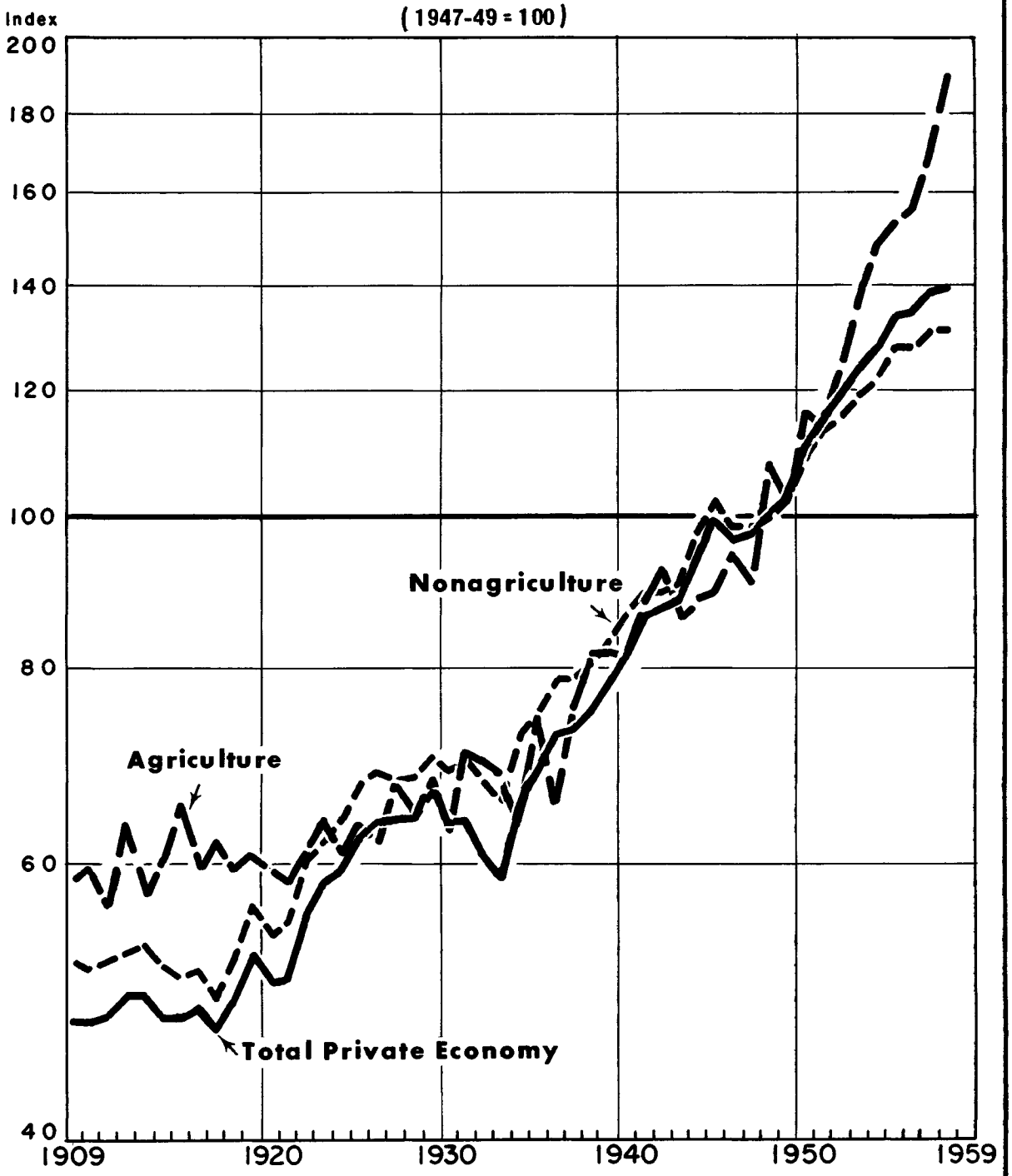

Table 6. Average annual percent change in real product per man-hour 1909-58 1/

Sector	Average annual percent change	
	BLS	Census
Total private 2/.....	2.3	2.4
Agriculture.....	2.1	2.1
Nonagriculture.....	2.0	2.1

1/ Output per man-hour series based on real product data from the Office of Business Economics, and unpublished man-hours data prepared by John W. Kendrick linked in 1947 to BLS or Census man-hours.

2/ The average change in the total is higher than that for either component because of shifts in the relative importance of the two sectors.

following World War I, 1920-30, the average annual increase in output per man-hour was higher than the long-term average, 1909-58, but lower than the average for the 11 years following World War II. The two major component sectors showed a different relationship. In agriculture, the increase was very small in the early period, very large in the later period. In nonagriculture, the average increase for the earlier period was roughly the same as for the later period.

Analysis of the various short-term movements within the long-term period points up the fact that there have been previous subperiods as well as the post-World War II period which have shown higher than average increases in output per man-hour. In this sense, the experience of the post-World War II period is not unique. 13/

The overall movement of output per man-hour for the entire long-term period, 1909-58, can be described by the straight line trend, as previously indicated, which shows an average annual increase of 2.3 or 2.4 percent (based on BLS and Census man-hours, respectively). However, there appear to be one or more changes in the direction of trend during this period. For example, these data indicate that in the early years, 1909-19, there was very little gain in output per man-hour (an average annual increase of 0.4 percent), while for the period 1919-58, the average annual increase was 2.6 percent. There appears possibly to have been another mild change in direction in the middle or late 1930's, and the average increase for the period 1939-58 was 2.9 percent per year.

Another technique for examining the overall movement in output per man-hour, which takes into account these changes in direction, is that of fitting a curve mathematically to the data. 14/ There are, however, various forms which a derived curve can take, and these may yield different results.

One form of curve is a parabola, which implies a constant and continuing change in the rate of growth in output per man-hour. In other words, this curve assumes constant acceleration in the rate of change in output per man-hour. 15/

13/ This observation is consistent with the finding of the National Bureau of Economic Research. For example, Solomon Fabricant indicated in Basic Facts on Productivity Change, Occasional Paper 63, NBER, New York, 1959, p. 38, that "It may surprise those people who have heard of the 'new' technological age that output per man-hour (and also output per weighted man-hour) rose during the period after the war at an average rate, that, though high was within the range of experience for earlier periods of similar length."

14/ Curves describing past trends in output per man-hour have also been used by J. Frederic Dewhurst and Associates in America's Needs and Resources, 20th Century Fund, New York, 1955, p. 42; and Milton Lipton in the Conference Board Business Record, February 1956. National Industrial Conference Board, New York, p. 58.

15/ For a more detailed description of this curve and other curves, see appendix E, pp. A-37-44.

A parabola fitted to the indexes for 1909-58 indicates that the annual rate of growth in output per man-hour for the total private economy increased by 0.06 percentage points each year. This means that if the increase in output per man-hour in 1 year was 2.0 percent, the rate for subsequent years would be 2.06, 2.12 percent, etc., until it becomes, in 1958, 3.7 percent based on BLS man-hours, and 3.9 percent based on Census man-hours (table 7). 16/

The hyperbola, another second degree curve which may be fitted to the data, also implies a constantly changing rate of gain in output per man-hour. In the case of this curve, however, the rate of gain does not increase indefinitely but eventually reaches an upper limit. This curve fitted to the output per man-hour indexes from 1909 to 1958, has a somewhat smaller acceleration, so that the 1958 derived average rate of change is 3.5 percent based on BLS man-hours and 3.7 percent based on Census man-hours (table 7).

In addition to the form of statistical description, the length of time period considered and the particular data used may also have considerable influence on the measure of trend. For example, using estimates of output per man-hour derived by Fabricant for the period 1889-1957 17/ and applying the parabola type curves to his estimates, the derived 1958 rate of increase in output per man-hour from a curve covering the period 1909-57 is 3.5 percent, whereas the derived rate from a curve covering the long period 1889-57 is 3.3 percent per year. In the study America's Needs and Resources, estimates of output per man-hour are presented beginning with the year 1850. In this study, Professor Dewhurst fitted a parabola type curve for the period 1850-1950, using data for every 10th year. The derived 1958 rate from this curve is 2.2 percent. If similar type curves for these data from 1890 to 1950, and from 1910 to 1950 are computed, the derived 1958 rates are 2.8 and 5.0 percent, respectively (table 7). 18/

16/ This finding is also consistent with that of the National Bureau of Economic Research in the 39th Annual Report of the NBER (p. 4)...Fabricant says "Also--a fact of great importance--the long term pace of advance in output per man-hour has been speeded up. It was 22 percent per decade during the quarter century preceding World War I. It has averaged 29 percent since. During the most recent period--after World War II--national product per man-hour has been rising at an even greater rate, 35 to 40 percent per decade."

17/ Solomon Fabricant, op. cit., pp. 43-45. The real product data in the Fabricant output per man-hour series used different price weights for each decade which reflected the average price of the first and last year of the decade. The real product data from the Office of Business Economics used in this report are based on 1954 price weights for the entire period.

18/ J. Frederic Dewhurst, op. cit., p. 42. The Dewhurst estimates are based on deflated private national income in 1950 prices, covering the period 1850-1952. Trends based on data for selected years may yield results which differ from those based on data for every year within the period. The differences may be larger as the period covered is reduced. In particular, it should be noted that trends derived from data for the period 1910-50 are based on only 5 observations.

Table 7. 1958 derived rate of change in output per man-hour for the private economy based on various long-run trend measures 1/

Item	Series and period covered by trend measures						
	BLS 2/ 1909-58	Census 3/ 1909-58	Fabricant 4/ 1909-57	Fabricant 4/ 1889-57	Dewhurst 5/ 1910-50	Dewhurst 5/ 1890-1950	Dewhurst 5/ 1850-1950
	1958 Derived Rate						
Linear							
Total	2.3	2.4	2.6	2.3	1.9	1.7	1.7
Agricultural-nonagricultural proportions constant with--							
1909 output proportions	2.1	2.1					
1958 output proportions	2.1	2.1					
1909 man-hour proportions	2.1	2.1	6/ 2.3	6/ 2.0			
1958 man-hour proportions	2.0	2.1					
Adjusted for changes in capacity utilization 7/	2.3	2.3					
Curvilinear-parabola							
Total	3.7	3.9	3.5	3.3	5.0	2.8	2.2
Agricultural-nonagricultural proportions constant with--							
1909 output proportions	3.6	3.7					
1958 output proportions	3.2	3.3					
1909 man-hour proportions	3.1	3.3	6/ 2.8	6/ 2.9			
1958 man-hour proportions	2.9	3.1					
Adjusted for changes in capacity utilization 7/	3.3	3.5					
Curvilinear-hyperbola							
Total	3.5	3.7					

Footnotes to table 7

1/ Computed from the least squares trend measures of the logarithms of the index numbers.

2/ Output per man-hour series based on real product data from the Office of Business Economics, U.S. Department of Commerce, and unpublished man-hours data prepared by John W. Kendrick linked in 1947 to BLS man-hours.

3/ Output per man-hour series based on real product data from the Office of Business Economics, U.S. Department of Commerce, and unpublished man-hours data prepared by John W. Kendrick linked in 1947 to Census man-hours.

4/ Indexes of output per unweighted man-hours, Solomon Fabricant, Basic Facts on Productivity Change. Occasional Paper 63, National Bureau of Economic Research, Inc., 1959, table A.

5/ Estimates of private national income per man-hour in 1950 prices in J. Frederic Dewhurst, America's Needs and Resources, Twentieth Century Fund, 1955, table 14.

6/ Indexes of output per weighted man-hour. Solomon Fabricant, op. cit. This series holds constant the relative importance of a number of industries, in terms of man-hours.

7/ Employment-labor-force ratio is used as an approximation of the degree of capacity utilization.

The actual indexes in any year may differ substantially from the derived measure, whether linear or curvilinear. Over the long-run period, the deviations (or more technically the sum of the squared deviations) of the actual indexes from the derived curves are smaller than those from the straight line. Of the two types of curves which were computed for the period 1909-58 (based on Census or BLS man-hours), the hyperbola shows somewhat smaller deviations than the parabola. In this sense, the various curves may be referred to in statistical terminology as providing a "better fit," 19/ but this does not mean "better" in an absolute sense, i.e., better for all purposes of analysis.

The curves and the straight line are only mathematical summaries of movements in output per man-hour which result from the action of many contributory elements. An analysis of these elements is needed to understand their contribution to the overall movements summarized by these mathematical expressions of trend.

Major Sectors

One of the primary reasons for any evidence of acceleration in output per man-hour for the private economy during the last half century was the extraordinary gain which took place in the rate of growth of agriculture. Over the whole period 1909-58, output per man-hour in this sector increased at an average annual rate of 2.1 percent (table 6). However, there appear to have been two distinct changes in the trend for agriculture. In the earlier years, 1909 to the 1930's, the average increase was quite modest, about 1.1 percent per year. The rate of increase picked up substantially in the mid-thirties and again at the end of World War II, averaging about 6.2 percent after 1947 (charts 4 and 5).

The sharp rise which emerged in the thirties probably reflects the efforts made to help the farmers during the depression. Programs aimed at stabilizing the farmer's market, increasing the availability of farm credit, and stimulating Government research and education for farmers all had their effect.

The phenomenal rate of growth in agricultural output per man-hour after World War II reflects notable advances in the application of technology, electricity, and the science of chemistry and biology to farming. Accompanying these advances were reduced use of marginal or submarginal lands and increases in the relative importance of large-scale farms. Farm population also continued to decline during this period.

The average annual increase in output per man-hour for the nonagricultural sector was 2.0 or 2.1 percent from 1909-58 (computed by the straight line method as compared with the postwar averages of 2.4 and 2.9 percent based on BLS and

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19/ Strictly speaking, the usual tests for better fit do not apply to time series data such as those used in this report. (For further details see appendix E.)

Census man-hours, respectively. In examining the trend over the longer period of time, there seem to have been three cycles in which the average increase was greater than over the long term, but, as indicated earlier, these were affected by the depth of the trough and the speed of recovery during the period.

In contrast to agriculture, the indexes for nonagriculture do not seem to exhibit continuing sharp changes in direction. A slight degree of curvilinearity can be obtained by fitting a curve to the data, but this arises almost entirely from very small gains over the first decade, 1909-19, and the dips and recoveries which occurred subsequent to that period. When data for the nonfarm sector covering the period 1919-58 are adjusted for changes in degree of capacity utilization during the period, there remains no evidence of curvilinearity. 20/

Output per man-hour for the nonagricultural sector is also influenced by the movements of its component industries and industry groups. The limited information available indicates substantial differences in rates of growth among these components, some of which had much higher than average increases.

In short, the movements in output per man-hour for the agricultural and nonagricultural sectors have contributed differently to the movements for the private economy. In the nonagricultural sector, there was a fairly steady increase in output per man-hour after 1919, despite important cyclical and irregular fluctuations. In the agricultural sector, where there were also wide and irregular fluctuations, the gains were moderate at first, but rose sharply later, especially in the last decade.

Measures Excluding the Effects of Shifts between Agriculture and Nonagriculture. As mentioned earlier, shifts in the relative importance of industries and major sectors can also influence the movement of output per man-hour for the total private economy. Estimates have been developed for the 1909-58 period which exclude the effect of part of these shifts, i.e., the shift between agriculture and nonagriculture. Over the entire 50-year period, the average annual increase in output per man-hour, excluding the effect of shifts between these two sectors, was 2.1 percent compared to the change of 2.4 percent, including the effect of shifts, based on Census man-hours. 21/ The estimates based on BLS man-hours were affected similarly (table 7).

In some shorter periods, the changing relative importance of agriculture and nonagriculture had dramatic effects. For example, in the earlier years of the depression, 1929-33, nonagricultural man-hours dropped about 32 percent while agricultural man-hours decreased only 2-1/2 percent. Consequently,

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20/ For a more detailed discussion of adjustments for changes in the degree of capacity utilization, see pp. 28 and 29.

21/ These rates were the same whether the man-hour composite or the output composite were used and whether the composites were fixed as of 1909 or 1958.

agriculture became relatively much more important in terms of man-hours. Partly as a result of this manpower shift, output per man-hour for the total private economy showed a rather substantial drop (12 percent) in the period 1929 to 1933--greater than the change for either sector separately. The exclusion of the effects of shifts reduced the downward bulge in output per man-hour for the total private economy during the 1930's. Although some years were substantially affected by shifts, the general cyclical pattern of movement in output per man-hour over the entire period was about the same whether the shifts were included or excluded. The same cycles were found, with troughs occurring in the same years, 1917, 1933 and 1946.

Shifts in the relative importance of the sectors may affect not only the average rate (based on a straight line) of output per man-hour but also the increase in the rate (acceleration). It has already been indicated that excluding the effect of shifts reduced somewhat the average annual rate of increase over the long-term period. If one of the curves (parabola) is fitted to the long-term indexes of output per man-hour, computed so as to hold the relative importance of agricultural and nonagricultural sectors constant, the derived rate still shows an acceleration. It is generally smaller, however, than that obtained from the curve fitted to the data including the effect of shifts. The 1958 average annual change in output per man-hour derived from this new curve averages around 3.0 percent when the 1958 agricultural-nonagricultural man-hour proportions are held constant, and around 3.2 percent when the corresponding output proportions are held constant (table 7).

Here again, the time period chosen for comparisons affects the trend measures. The Fabricant series from 1889, which uses weighted man-hours, shows a reduced rate of acceleration. 22/ In this case, the derived 1958 rate of growth in output per man-hour is 2.9 percent per year (table 7).

Relationship of Trend to Capacity Utilization. The irregular and cyclical fluctuations in output per man-hour are caused in part by variations in the degree to which the economy's productive capacity is being utilized. Output per man-hour tends to be high when the economy is operating at high rates of capacity utilization, such as during periods of prosperity, and tends to be low during periods of depression.

Since the rates of capacity utilization are not constant from year to year, the changes in these rates may also affect the rate of change in output per man-hour over the long run. When a straight trend line is computed in which an allowance for the effect of changes in the degree of capacity utilization is made, the average annual rate is 2.3 percent for both the Bureau of

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22/ Fabricant's weighted man-hours series is designed to remove the effect of shifts in the importance of various sectors. Solomon Fabricant, op. cit.

Labor Statistics and Bureau of the Census based series. 23/ This is roughly the same as the average annual rate derived when use of productive capacity is not held constant (table 7). On the other hand, when one of the curves, such as the parabola, is derived from indexes holding the degree of capacity utilization constant, the acceleration rate is reduced. In this case, the average annual change for 1958 becomes 3.3 percent for the series based on BLS man-hours and 3.5 percent for the series based on Census man-hours. This would indicate that the dips in the level of capacity utilization, particularly during the depression, and the subsequent recoveries contributed in part to the acceleration in output per man-hour computed for the total private economy.

Summary

The average annual increase in output per man-hour for the total private economy for the postwar period, 1947-58, was higher than that for the long-term period, 1909-58. At the same time, a review of the movements of output per man-hour during the last half century indicates that the postwar period was not unique and that there were other short-term periods in which the average increase was higher than the long-term rate. Of course, there were also others in which the average was lower.

There are various ways in which the long-run experience can be examined. The measures of trends for this period are influenced to a very large extent by the particular form of statistical description which is employed, the length of time which is being considered, the movements within component sectors, the effect of shifts in the relative importance of these sectors, the degree of capacity utilization which the economy is experiencing and finally, the particular data themselves.

The simplest form of statistical description, the long-term average change (straight line), shows a rate of increase for the long-term period substantially below that of the post-World War II period. Fitting various second degree curves to the data indicates that some factors have been working toward an increased rate of output per man-hour in the economy as a whole. The acceleration seems to have resulted primarily from the spectacular performance of one sector of the economy--agriculture--which rose moderately in the earlier years and very rapidly in the later years of the period. In contrast, the nonagricultural sector did not show this kind of acceleration. In addition, shifts in the relative importance of major sectors and changes in the degree of capacity utilization also contributed to this increase in the overall rate of growth.

23/ Since estimates of physical capacity utilization are not available, the ratio of employment to the labor force is used as an approximation. This approximation is also used by John W. Kendrick in National Productivity and its Long Term Projections, Conference on Research in Income and Wealth, May 1951, (published by Princeton University Press, Princeton, 1954) although his technique differs slightly.

An important point to be considered in connection with the various long-term calculations presented is that they apply only to the period measures, 1909-58. A change in the period covered influences the degree of acceleration and the statistical description. Moreover, these trends cannot be mathematically extended into the future without appropriate consideration of the various economic and institutional conditions which may affect growth, and the probable, or estimated, movement of component sectors under these various conditions.

FACTORS AFFECTING OUTPUT PER MAN-HOUR

Technology

A major factor in the long-term growth of output per man-hour has been the influence of technological innovations. The flow of new products, new materials, new processes, and new equipment as a result of the application of science and engineering has given American industry a dynamic character.

Technological advances since 1947 have been built upon the cumulative progress of machine production that began in the 19th century and continued in the 20th. The decade of the 1920's, when output per man-hour in manufacturing rose sharply, saw the extension of mass production, the electrification of industry, the rise of the chemical and auto industries, and the growth of more rational plant management. Even during the depression of the 1930's, technical innovations in production were extended in many fields. While World War II held back improvements in the plant and equipment of civilian goods industry, impressive technical advances were made in the mass production of war materials. Thus, as a result of cumulative technological developments over nearly four decades, advances in output per man-hour in manufacturing started from a level in 1947 about twice that of 1919.

The period since 1947 has witnessed an impressive flow of technological innovations in American industry. Faced with an unprecedented backlog of demand, industry used inventions previously considered uneconomic, adapted military developments to civilian purposes, and developed new products through research. Technological change has been widespread, affecting consumer and producer goods, industry and agriculture, and goods and service industries.

Extensive changes have been made in production processes and equipment. Table 8 shows the substantial progress since 1947 of some major developments that were introduced prior to World War II in different sectors of the economy. Such changes have important implications not only for labor requirements but also for the amount of capital, equipment, fuel, and materials used and for the quality of goods and services produced.

Technological advances in processes and equipment that have been introduced since 1947 and are important factors in a variety of industries may be summarized under six broad trends: further improvement in the speed and capacity of automatic machinery; greater use of conveyors in materials handling; greater use of instrumentation; further integration of processing and handling; greater application of automatic control; and more extensive use of electronic-data processing. The term "automation," a contraction of the word "automatization," is often used to describe technological advances such as transfer machines, electronic computers, and feedback controls that are designed for more automatic operation than hitherto possible.

Table 8. Some indicators of technological changes in United States industries, 1939 and 1947-58

Item	1939	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1. Diesel locomotives (diesel electric locomotives as percent of total number).....	1.4	14.7	20.2	27.8	35.9	44.8	55.7	65.0	72.1	79.2	85.9	90.0	93.4
2. Dial telephones (dial telephones as percent of all Bell System phones).....	55.7	65.6	68.1	73.0	75.5	77.4	79.1	81.3	84.0	87.0	89.8	92.1	93.8
3. Catalytic cracking in oil refineries (catalytic cracking as percent of total cracked gasoline capacity).....	1/5.1	28.0	31.1	35.2	40.0	42.1	45.0	46.8	49.3	52.0	50.8	50.0	45.4
4. Mechanical loading in bituminous-coal mining (percent of underground production mechanically loaded).....	31.0	60.7	64.3	67.0	69.4	73.1	75.5	79.6	84.0	84.6	84.0	84.8	84.9
5. Tractors on farms (exclusive of steam and garden) (in millions).....	1.4	2.6	2.8	3.1	3.4	3.7	3.9	4.1	4.2	4.3	4.5	4.6	4.7

1/ As of January 1, 1941.

Sources:

Line 1. Interstate Commerce Commission. 2. Federal Communications Commission.
3. and 4. U.S. Bureau of Mines. 5. U.S. Department of Agriculture.

Information about the extent of use and the actual effects of such developments as automation, compared to the results of more conventional equipment, is still fragmentary and more study is needed for an evaluation of their actual or potential implications for the economy.

Level of Investment

Fixed Capital in Relation to Employment, Man-Hours, Output. The increase in output per man-hour of the private economy in the United States, both in the long run and in the post-World War II period, has been accompanied by substantial growth in the amount of fixed capital available per worker. Although deriving a precise measure of the use of fixed capital per worker involves many conceptual and statistical problems, the trends indicated by the various estimates are in reasonably close agreement on this point. In the discussion which follows, capital stock is defined as the value of plant and equipment, excluding working capital, inventories, etc. The estimated values of the stock are gross values. That is, the stock is included at its full, gross value for each year of its useful life; the entire value is deducted at the end of its useful life. 24/ The capital stock is stated in constant dollar terms, the effect of price changes having been removed. Comparisons are made of the postwar years 1947-56 with the prewar period 1925-29 (assigned the value of 100), and the year 1941 so as to eliminate years of abnormal utilization of capital stock. The results may be summarized as follows:

1. Capital equipment per person engaged in production has risen substantially since the period 1925-29. Equipment per person in 1956 was almost twice as high but plant per person was only slightly higher, so the combined stock of plant and equipment per person was about one-third higher (table 9). Most of these increases occurred during the postwar period, largely because capital investment was low in the depression years of the 1930's and civilian production was limited during the war years. It should be noted that the increases indicated for the early postwar years are possibly too high because the assumptions regarding "normal" life of equipment used in the estimates may not have been valid for the war and immediate postwar period. The postwar increase was not confined to the earlier years, however. For example, equipment per person increased about 37 percent between 1950 and 1956.

2. Equipment, plant, and total stock per man-hour have risen faster than per person over the long run, as a result of the decline in average hours per employee (table 10). That is, while capital stock rose 82 percent, employment increased 35 percent and total private man-hours increased 9 percent (based on Census data) from the 1925-29 average to 1956. However, the difference between man-hour and employment trends has not been a major factor in the postwar period.

24/ The data on capital stock are from the Machinery and Allied Products Institute, see table 9.

Table 9. Indexes of persons engaged in private industry and stock of fixed capital per person, 1941 and 1947-56

(1925-29=100)

Year	Persons engaged	Stock of fixed capital (constant 1953 prices)			Stock of fixed capital per person		
		Total	Plant	Equipment	Total	Plant	Equipment
(1)	(2)	(3)	(4)	(5)	(3) ÷ (2) (6)	(4) ÷ (2) (7)	(5) ÷ (2) (8)
1941.....	111	115	114	118	104	103	106
1947.....	124	126	116	143	102	94	115
1948.....	127	132	119	157	104	94	124
1949.....	125	138	121	170	110	97	136
1950.....	128	143	123	183	112	96	143
1951.....	129	150	125	197	116	97	153
1952.....	129	156	128	211	121	99	164
1953.....	131	163	131	225	124	100	172
1954.....	128	169	134	238	132	105	186
1955.....	132	174	136	247	132	103	187
1956.....	135	182	139	264	135	103	196

Source: Col. 2.--Estimates 1925-29 and 1941 based on table 2 of the Joint Economic Committee report, Productivity, Prices and Incomes. Washington, D.C., 1957. Estimates 1947-56 from table A-2, line 7. Persons engaged include wage and salary workers, active proprietors of unincorporated businesses, and unpaid family workers.

Cols. 3-5.--Machinery and Allied Products Institute. Indexes computed from data in Statistical Notes to Capital Goods Review, Washington, D.C., No. 23, August 1955 as revised.

Table 10. Indexes of man-hours in private industry and stock of fixed capital per man-hour, 1941 and 1947-56

(1925-29=100)

Year	Total private man-hours	Stock of fixed capital per man-hour		
		Total	Plant	Equipment
(1)	(2)	(3)	(4)	(5)
1941.....	99	116	115	119
1947.....	105	120	110	136
1948.....	107	123	111	147
1949.....	104	133	116	163
1950.....	105	136	117	174
1951.....	107	140	117	184
1952.....	107	146	120	197
1953.....	107	152	122	210
1954.....	103	164	130	231
1955.....	107	163	127	231
1956.....	109	168	128	242

Source: Col. 2.--1925-29 and 1941 derived by linking Census based man-hour series in 1947 to the unpublished man-hour data compiled by John W. Kendrick. 1947-56, table A-2, line 16.

Cols. 3-5.--Col. 2 divided into cols. 3-5, table 9.

Table 11. Indexes of total private real product and fixed capital per dollar of real private product, 1941 and 1947-56

(1925-29=100)

Year	Total private real product	Fixed capital per dollar of real private product		
		Total fixed capital	Plant	Equipment
(1)	(2)	(3)	(4)	(5)
1941.....	134	86	85	88
1947.....	161	78	72	89
1948.....	167	79	71	94
1949.....	166	83	73	102
1950.....	181	79	69	101
1951.....	192	78	65	103
1952.....	198	79	65	107
1953.....	208	78	63	108
1954.....	205	82	65	116
1955.....	223	78	61	111
1956.....	229	79	61	115

Source: Col. 2.--U.S. Income and Output, a Supplement to the Survey of Current Business, 1959, tables I-13 and I-16, U.S. Department of Commerce.

Cols. 3-5.--Col. 2 divided into cols. 3-5, table 9.

3. For the long-run period, the rate of increase in output (GNP) exceeded the increase in total capital. In the postwar period, however, output and total stock of fixed capital have moved at the same rate (table 11).

In studying the components, it is clear that these relationships have been achieved by compensating changes in plant and equipment. Equipment per dollar of output has increased in both the long-run and the postwar period, while plant per dollar of output has declined in the long run and remained fairly stable in recent years. Translated into man-hour ratios, this means that in the postwar period, output per hour has kept pace with total capital per hour but has increased less than equipment per hour.

Limitations. Before making some observations concerning the significance of these trends, certain limitations of the data must be pointed out.

1. The procedure used for valuing capital stock in constant dollars does not adequately reflect the improved quality of the equipment. If these improvements could be more adequately reflected, the index of equipment would be even higher.

2. Furthermore, the measurement of capital stock does not cover the increased service that may be obtained from plant and equipment through improved management and organization techniques, which have received considerable attention in the postwar period. This limitation, however, applies equally well to other factors of production, such as labor.

3. Finally, because of the standard accounting procedures followed in estimating useful life, the value of capital does not reflect the continued use of equipment already depreciated, or equipment scrapped because of obsolescence. Over-intensive use was common during the war and the value of capital actually in use in the early postwar years is understated because large amounts of equipment, written off for accounting purposes, were still being used. Obsolescence becomes important in a period of rapid technological innovation, but the extent of premature scrapping of equipment in recent years is not known.

Observations. The trends summarized above would appear to justify the conclusion that the significant increases in capital stock have been a major influence in the achievement of increased output per man-hour in the United States. However, the data raise some questions concerning the demonstrated relationship among output, capital, and labor input. While complete answers to these questions cannot be given, some general observations may be made.

1. Immediately apparent is the divergence in the movement of plant and equipment. This may be attributed in part to the fact that construction costs in the postwar period have been relatively higher than equipment costs. More important, probably, are the characteristics of the changing technology requiring less plant in relation to equipment. Another factor may be the increase in the relative importance of industries with higher-than-average equipment in relation to plant.

2. The capital-output and capital per man-hour ratios are also affected by changes in working hours. Generally speaking, each additional hour that a plant and its equipment are used results in an additional amount of output, thereby raising the output per unit of capital.

The secular decline in hours of work may have resulted in a decline in the output per unit of capital due to the increased proportion of the day in which the capital is not utilized. This decrease may have been offset, however, by an increase in output stemming from the advances in output per man-hour following the reduction in hours of work. There is no simple factor by which one may estimate how much of the change in output per unit of capital can be accounted for by the decline in average weekly hours worked, because many factors in addition to those indicated above must be taken into consideration, such as the extent of multiple-shift operations and the importance of continuous process industries.

In this connection, the ratios are also affected by the actual use which is made of fixed capital as distinguished from its availability. Estimates by the Department of Economics of McGraw-Hill Publishing Co. indicate that part of the increase in plant and equipment during the postwar period has gone into standby capacity. This would mean that the stock of capital actually used per worker has gone up somewhat less than the ratio of capital stock available per worker.

Electric Energy Per Man-Hour

It has already been indicated that the estimates of fixed capital per worker or per man-hour suffer from a number of limitations. In the first instance, the measures are based on estimates of "normal" useful life of various types of plant and equipment, and in the second, the ratios refer to available stock of capital and may therefore be affected by change in the proportion of capital stock actually utilized. One measure of productive capacity utilized, which bypasses some of these problems, although adding some others, is the amount of kilowatt hours of electric energy consumed per production worker man-hour. This measure more nearly reflects actual utilization, and also more powerful and efficient machinery to the extent that these factors are accompanied by increased electric energy consumptioin.

Estimates have been prepared for manufacturing showing the KWH consumed per production worker man-hour, both for (a) all industries combined, and (b) excluding the primary metals and chemical industries. The ratios of KWH per production worker man-hour are shown in table 12.

Table 12. Electric energy (KWH) consumed per production worker man-hour, selected years, 1929-57

Year	All manufacturing	Primary metals and chemicals excluded
1929	2.9	(1/)
1939	4.7	3.3
1947	5.8	3.8
1953	8.0	5.1
1954	10.2	5.6
1955	11.6	5.9
1956	12.4	6.2
1957	12.9	6.4

1/ Not available.

Source: Bureau of the Census, Census of Manufactures, 1939, 1947, and 1954, and Annual Survey of Manufactures, 1949 through 1957.

The figures on either basis indicate substantial and continued increases in electric energy consumed per man-hour. By 1957, KWH consumed per production worker man-hour for all industries combined was over 300 percent higher than in 1929 and almost 175 percent higher than in 1939.

Electric energy consumption presents a problem as an indicator of production activity, however, to the extent that a significant amount of KWH consumed is not used simply to drive machinery or for lighting, but is being increasingly used in heat treatment of metals, arc and spot welding, and other heating forms, rather than in producing motion. It is also being used as part of the manufacturing process in the aluminum, steel, and chemical industries. In these latter uses, consumption of electricity per unit of output would generally be well above the energy requirements of driving machines. Even if one excludes these latter industries, the increase between 1939 and 1957 was more than 90 percent. It should also be stated that on the basis of more complete data, almost all of the increase since 1939 occurred during the postwar period.

Thus, technology, as illustrated by selected technological developments, by stock of plant and equipment per worker, or by electric energy consumed per worker, has had a major effect on the ability of the economy to produce more with each man-hour worked.

Growth of Nonproduction Workers in Manufacturing

In the analysis of postwar trends in output per man-hour, it was indicated that manufacturing output per man-hour based on the man-hours of all persons employed in manufacturing had increased less than output per production worker man-hour.

Manufacturing output per man-hour of all persons employed increased by about 2.9 percent per year during the period 1947-57. The measure based on production worker man-hours showed an increase of about 3.7 percent per year. The difference between the two is due to the increase in employment of nonproduction workers in relation to production workers. 25/ In 1947, about one in every six employees was a nonproduction worker; by 1957, the proportion of nonproduction workers had increased to almost one in every four employees.

In terms of man-hours, production worker man-hours reached a peak in 1953 which was 8.4 percent higher than in 1947 (table 13), but by 1957, they had declined to about the same level reached in 1947. Nonproduction worker man-hours, on the other hand, increased almost continuously, and by 1957, they were about 55 percent higher than in 1947. 26/ Thus, the divergence between alternative output per man-hour measures based on production workers and all employee man-hours has increased, particularly since 1953.

In addition to affecting the trend in manufacturing real product per man-hour for the period as a whole, the increase in nonproduction workers in relation to all employees has affected the change in manufacturing output per man-hour in at least two other respects: (a) by increasing the proportion of relatively fixed or overhead type of personnel, it has modified considerably the cyclical pattern of output per man-hour based on production worker man-hours alone, and (b) the change in occupational structure, particularly within the nonproduction worker category, has made more indirect the relationship between production and man-hours during a given period of time.

25/ The Bureau of Labor Statistics defines production workers to include "all nonsupervisory workers (including working foremen) engaged in fabricating, processing, assembling, inspecting, receiving, storing, handling, packing, warehousing, and shipping; also workers engaged in maintenance, repair, janitorial and watchmen services, product development, and auxiliary production for a plant's own use (e.g., powerplant), and recordkeeping and services immediately associated with these production operations." Nonproduction workers include persons engaged in "executive, purchasing, finance, accounting, legal, personnel cafeteria, medical, professional, and technical activities; sales, sales delivery, advertising, credit, collection, installation, and servicing of the firm's own products; routine office functions, factory supervision, and force-account construction.

26/ Based on the assumption that nonproduction workers in manufacturing were paid for a 40-hour week during the postwar period 1947-57. Man-hours of proprietors are based on Census labor force data and are higher.

Table 13. Manufacturing real product per man-hour, 1947-57

(Man-hour estimates based on Bureau of Labor Statistics data)

(1947-49=100)

Year	Real product	Man-hours			Real product per man-hour	
		All 1/ persons	Production workers	Nonproduction workers 2/	All persons	Production workers
1947....	100.9	103.4	104.7	97.4	97.6	96.4
1948....	103.0	102.9	103.3	101.8	100.1	99.7
1949....	96.0	93.6	92.1	100.8	102.6	104.2
1950....	111.1	101.5	101.0	103.5	109.5	110.0
1951....	121.8	109.5	108.4	115.2	111.2	112.4
1952....	125.5	111.1	108.3	124.6	113.0	115.9
1953....	138.1	116.7	113.5	133.0	118.3	121.7
1954....	125.1	106.6	101.2	133.0	117.4	123.6
1955....	141.3	112.5	107.7	136.7	125.6	131.2
1956....	145.0	114.1	108.0	144.8	127.1	134.3
1957....	143.0	112.0	104.1	151.2	127.7	137.4
	Percent change over previous year					
1948....	2.1	-0.5	-1.3	4.5	2.6	3.4
1949....	-6.8	-9.0	-10.8	-1.0	2.5	4.5
1950....	15.7	8.4	9.7	2.7	6.7	5.6
1951....	9.6	7.9	7.3	11.3	1.6	2.2
1952....	3.0	1.5	-0.1	8.2	1.6	3.1
1953....	10.0	5.0	4.8	6.7	4.7	5.0
1954....	-9.4	-8.7	-10.8	0.0	-0.8	1.6
1955....	12.9	5.5	6.4	2.8	7.0	6.1
1956....	2.6	1.4	0.3	5.9	1.2	2.4
1957....	-1.4	-1.8	-3.6	4.4	0.5	2.3

1/ Includes a small number of manufacturing proprietors.
2/ Assumes a 40-hour week for nonproduction workers.

Regarding the effect on the cyclical pattern of output per man-hour, the increasing importance of nonproduction workers as a percent of total employment tends to dampen increases in output per man-hour during periods of recession and to accelerate productivity gains during recovery periods. This results from the fact that, in general, production worker employment and man-hours decline during the downturn in the business cycle while nonproduction worker employment remains relatively stable. During recovery periods, hiring of nonproduction workers tends to lag behind that of production workers.

The divergent patterns of man-hours and output per man-hour of production and nonproduction workers during the course of the business cycle are shown in table 13. In 1949, a recession year, production worker man-hours declined 11 percent from 1948; whereas, the man-hours of all workers dropped only 9 percent because of the relatively small decline of 1 percent in the man-hours of nonproduction workers. As a result, the measure of output per man-hour of all employees went up less in 1949 than that based on production workers alone. In the recovery period of 1950, the reverse situation occurred; and man-hours of production workers increased much more than those of nonproduction workers so that output per production worker man-hour increased less than output per man-hour based on man-hours of all workers. This pattern of divergence occurred in the cycle of 1954-55 and also in 1957, except that in the latter case, employment and man-hours of nonproduction workers actually increased while man-hours of production workers were declining.

One implication, therefore, of the increasing importance of nonproduction workers in manufacturing, and probably for the economy as a whole, is that it tends to reinforce the dampening effect on increases in output per man-hour during periods in which the economy shows either relatively small increases in real output or actual declines during recessions. This factor is probably part of the explanation for the slowing down in the rate of increase in output per man-hour during 1956 and 1957, when real product showed only a small increase and then started to decline.

The increasing proportion of nonproduction workers in the postwar period seems to be associated with several factors, including the large expenditures during the period for new plant and equipment and for expanded research and development activities. This has resulted in a direct increase in nonproduction workers (such as engineers, scientists, and other technical workers). In addition, a number of overhead functions were introduced or expanded which led to increases in clerical professional, and sales personnel, and workers in other nonproduction activities. 27/

27/ For a fuller discussion of the growth in nonproduction workers, see Nonproduction Workers in Factories, 1919-56 (in Monthly Labor Review, April 1957, pp. 435-440).

Some indication of the effect of these developments on the occupational structure of nonproduction workers in manufacturing is provided in table 14, based on Census labor force data. 28/ These estimates indicate that in recent years most of the expansion in employment among nonproduction workers was attributable to the increased hiring of professional, technical, and kindred workers. The number of professional workers increased by approximately 45 percent from 1952 to 1957, with most of the increase occurring between 1955 and 1957--27 percent. During this period, the professional group increased in relative importance from 22 percent of all nonproduction workers in 1952 to 27 percent in 1957. The other nonproduction groups--managerial, clerical, and sales personnel also showed employment gains between 1952 and 1957, but the combined gain of these groups was less than that of professional workers.

To the extent that the growth in professional personnel with their supporting staffs of technicians, administrators, clerks, and skilled workers reflects expansion in research and development activities on new products and processes, planning for expansion, and modification of new productive capacity, and similar activities, then the increased employment may have little direct relationship to current production.

The growing importance of this category of employment therefore underscores the need for careful interpretation of short-run changes in output per man-hour of all persons employed. It also serves to emphasize the desirability of obtaining more data on the occupational structure and activities of both nonproduction and production workers in order to evaluate more adequately the changes in output per man-hour.

Research and Development

New production techniques and new products are the result of a long-term investment in research and development. Although research has been a feature of the American economy for many years, it has received an increasing amount of attention in recent years. More and more individual producers are establishing research facilities looking toward the improvement of productive processes and the development of products that may not be in production for several years to come.

28/ Murray Wernick, Occupational Shifts in Manufacturing Employment, speech before Cleveland Chapter, American Statistical Association, March 4, 1958.

Table 14. Change in number and occupational distribution of nonproduction workers in manufacturing industries, selected periods, 1952-57

Occupation	Percentage change in number		Percentage distribution by occupation		
	1952-57	1955-57	1952	1955	1957
Nonproduction workers	19	11	100	100	100
Professional	45	27	22	24	27
Managerial	8	5	21	20	19
Clerical	11	8	47	45	44
Sales	25	1	10	11	10

Source: Bureau of the Census, as given in unpublished paper by Murray Wernick, op. cit.

Studies for the National Science Foundation conducted by the Bureau of Labor Statistics 29/ provide information on the increase in recent years of the number of scientists and engineers employed in research and development activities and on expenditures for such activities. It is estimated that in early 1954 about 550,000 scientists and engineers were employed in American industry 30/ and of this group, about 400,000 were employed in manufacturing. About one-third of the scientists and engineers in manufacturing were engaged in research and development activities, and about two-thirds were employed in other than research and development activities, such as managerial, technical sales, production, analysis and testing, etc. By early 1957, the total number of scientists and engineers in industry had increased by 33 percent. The scientists and engineers engaged in research and development had increased even more--about 44 percent.

In addition to the scientists and engineers employed in research and development, large staffs of supporting personnel, such as technicians, administrators, clerks, and skilled workers were also required. It is estimated that the ratio of supporting personnel to scientists and engineers is almost 2 to 1.

Further evidence of the rapid expansion in research and development activities is found in the growth in expenditures for such activities. Research expenditures, which were relatively small prior to 1950, have increased substantially since then, partly under the impetus of defense contracts and also as a result of the need for improvements in products and processes in order to maintain or expand competitive positions. It is estimated by the National Science Foundation, 31/ that between 1953 and 1956, research and development expenditures increased from $5.4 billion to $9 billion. Of the $9 billion in 1956, $6.5 billion (or about 70 percent) represented industry research and development (including Government-financed research and development); the remainder represented the Government's own research and development activities and that of universities and nonprofit institutions. The comparable figure for industry in 1953 was $3.7 billion, indicating an increase of about 75 percent; between 1953 and 1956, in expenditures for research and development activities. The McGraw-Hill Publishing Company's Annual Survey of Business' Plans for New Plants and Equipment indicates a further increase of about 20 percent between 1956 and 1957 in expenditures for research and development by industry (including Government-financed projects).

29/ National Science Foundation, Science and Engineering in American Industry, Final Report on a 1953-54 Survey, NSF 56-16. Another National Science Foundation publication, Scientific Manpower Bulletin No. 10, December 1958, summarized data on employment of scientists and engineers for more recent periods, and its Review of Data on Research and Development, No. 10, May 1958, summarized data on research and development costs through 1956.

30/ Excludes employment in government and nonprofit institutions.

31/ National Science Foundation, Review of Data on Research and Development, No. 10.

While these expenditures on research and development have undoubtedly been a major factor in the advancement of technology and growth in real product per man-hour, tangible results may not be realized for a number of years subsequent to the original expenditures. The man-hours expended in this activity thus represent a kind of capital investment of manpower. The man-hours are included in the measure of labor input in the year in which the expenditure takes place but the output resulting from the activity is, like depreciation on capital, spread over a number of years. As a result, the relationship of output and man-hours (including man-hours expended on research and development activities) becomes, in the short run, more indirect and less stable as research and development increase in importance, as in the last few years.

Government and Education

Another underlying and pervasive factor affecting the growth in output per man-hour is the role of Federal, State, and local government investments in services and facilities. Examples of the type of public expenditures which have increased the effectiveness of private investment and productive activity are research activities undertaken or financed by the government, improved and more extensive highways, airports and waterways, water supply, etc. Widely diffused public and private educational activities have also contributed to a more efficient and skilled labor force, a major element in the continued growth in output per man-hour.

The Human Factors

Obviously, investment and technological advance could have little influence on output per man-hour without a competent and ingenious management to organize and administer the production process, and without a skilled, intelligent, and alert labor force to execute it. In this connection, it is interesting to note the observations of foreign productivity teams which have visited the United States since World War II. While their reports acknowledge the importance of technology, many of them stress the human factors which distinguish American industry--the maturity of labor relations and the freedom of collective bargaining, the skill of management, opportunities for personal advancement, attitudes of the worker, the extent of management and labor mobility, safety measures, and many other factors.

In brief, the skillful blending of human resources in a free economy has contributed to technological advance. The human factors in the productive process have been a strong, motivating force behind the adoption of technological innovations in the United States. The efficient adaptation of the innovations to industrial processes, in turn, has led to a long-term, high rate of productivity increase--one of the most important factors in the growth and strength of the American economy, and the foundation for its high standard of living.

OUTPUT PER MAN-HOUR IN RELATION TO REAL PRIVATE PRODUCT PER CAPITA

Using the information on output per man-hour for the postwar period developed in the previous sections, along with other data on population, employment, and average hours, it is possible to determine whether output per man-hour has continued its major contribution to the growth in real product per capita.

In general, real national product per capita is influenced by the proportion of the population employed, average annual man-hours, and the goods and services produced per man-hour.

The figures given in table 15 indicate quite clearly that the increase in real product per capita during the postwar period was due entirely to the increase in real product per man-hour. The increase in real private product per man-hour of 3.1 or 3.5 percent based on BLS or Census man-hours, respectively, was offset to some extent by declines in the proportion of the population employed and continuation of the long-run decline in working hours, with the result that real product per capita increased by about 1.9 percent. It may also be inferred that the contribution of output per man-hour towards continued increases in real product per capita would be true for both the total and private real product per capita.

It should be noted that the estimates for the postwar increase in real product per capita must be qualified, i.e., the gains in the early part of the postwar period followed a period of decline from the peak level reached during the latter part of World War II.

It may also be of interest to compare the estimate for the postwar period with that for the long run. Based on figures given in the study by Abramovitz, 32/ from 1869-76 to 1944-53, net national product per capita increased about 1.9 percent per year. During the same period, the proportion of the population employed (excluding the Armed Forces) increased by about 0.2 of 1 percent per year, but this was more than counterbalanced by the decline in average hours of work of about 0.3 of 1 percent per year. The long-run increase in real product per capita was therefore based entirely on the increase in output per man-hour, which amounted to about 2 percent per year.

32/ See Moses Abramovitz, Resources and Output Trends in the United States Since 1870, Occasional Paper 52, New York, 1956, National Bureau of Economic Research.

Table 15. Average annual percent change in real product, real product per capita, employed population, man-hours, and real product per man-hour, 1947-58

Item	Total economy	Private economy
Real product	3.7	3.6
Population	1.7	1.7
Real product per capita	1.9	1.9
Real product per capita is the product of:		
Proportion of population employed:		
1) Employment (Census)	- .7	-1.0
2) Jobs (BLS) 1/	—	- .7
Average annual man-hours:		
1) Census man-hours	—	- .6
2) BLS man-hours	—	- .5
Real product per man-hour:		
1) Based on Census man-hours	—	3.5
2) Based on BLS man-hours	—	3.1

1/ Because of multiple job holding, the total number of jobs held may exceed the number of persons employed.

APPENDIXES

Appendix A. Methods and Sources for Output per Man-Hour Estimates

Earlier in this report, the concept of real GNP per man-hour was described in general terms. The indexes are based on real product (GNP) and man-hours data from various sources (tables A-1 and A-2). In practice, the degree to which the computed ratios adhere to the concept depends upon the availability of data. In order to interpret the ratios and their limitations, it is important to understand the methods and sources actually used in estimating real product per man-hour for the total private economy and major sectors. The description which follows summarizes the major elements in deriving the estimates of real product and man-hours.

Real Product

Total Private Economy

The estimate of total private real product (private GNP in constant dollars) is taken directly from the series published by the National Income Division, Office of Business Economics, Department of Commerce. 1/ Gross national product is the market value of final goods and services produced by the economy. It comprises the purchases of goods and services by consumers, gross private domestic investment (including the change in business inventories), net foreign investment, and government. The value of intermediate goods and services consumed in the course of production are included in the value of final goods and services in which they are incorporated and are therefore not counted separately since this would lead to duplicating the value of intermediate goods and services.

"Final" goods and services are differentiated in general from "intermediate" products in that they are usually not purchased for further fabrication or resale. Transfers of existing assets are excluded. The coverage of final products is also limited in general to actual purchases in the market place. This latter definition is modified in some instances to include in final output items of production which are not actually purchased but are considered to be the equivalent of goods and services usually obtained by purchase. Examples are food furnished to employees, food produced and consumed on farms, and the rental value of owner-occupied homes.

1/ A description of the methods and sources used to develop both the current and constant dollar estimates of gross national product is given in the 1954 National Income Supplement to the Survey of Current Business, U.S. Department of Commerce. For further information on methods and sources, see Appendix F, Bibliography.

Gross national product is also equal to the income (national income) received by the various factors of production (labor and property) which arises from the current production of goods and services, plus the amount of capital consumption allowances, indirect business taxes, and certain other miscellaneous items. The major categories of gross national product in current dollars and the related (costs) payments incurred for the year 1957 are shown in table A-3.

Gross national product in current dollars cannot be used directly for the measurement of productivity since it would reflect change in value due to price change in addition to the change in physical volume. The National Income Division, Office of Business Economics, U.S. Department of Commerce, prepares and publishes estimates of constant dollar gross national product which are related to and complement their current dollar estimates.

In theory, gross national product in constant dollars can be obtained either by developing estimates of constant dollar gross product originating in each sector (output minus intermediate goods and services) and summing these to total gross national product or by converting the current dollar value of final goods and services into constant dollars. In practice, due to limitations of the data, only the latter method is used at the present time to develop the official estimates in the United States.

The current and constant dollar estimates of GNP and major components for 1954 and 1957, along with the implicit price deflators are shown in table A-4. It should be noted that this is a summary table and that both the current and constant dollar estimates are initially developed in considerable unpublished detail and then aggregated to the level shown in table A-4.

Before going on to a detailed discussion of some of the problems involved in developing the constant dollar estimates, some explanation must be made of the fact that the measure used in this report is limited to the private sector of the economy, excluding general government. The reason for the exclusion of general government is that there is no satisfactory method of measuring the goods and services provided by the government, either in current or constant dollars. Lacking an adequate measure for the output of government, the national income accounts adopt the convention that "output" of general government is equivalent to the compensation of government employees. This implies that in "real" terms, the productivity of general government employees is assumed to be constant. Although this is not the only area in the national income accounts where, for lack of adequate concept and data, output is equated with employee compensation, 2/ it is by far the largest single sector where this occurs. In addition, the proportion of employment accounted for by government (including the military) has increased significantly during the postwar

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2/ The domestic and some other personal services are other areas where output is equated with compensation.

period, particularly since 1950. It has, therefore, seemed preferable to limit the measure of national productivity to the private sector of the economy.

Included in the "private" sector, however, are those government activities whose major function involves the sale of a product or service. These activities, called government enterprises, include, for example, the Post Office, Tennessee Valley Authority, publicly owned local utilities, and similar enterprises.

Some of the major problems in the measurement of current and constant dollar private gross national product, particularly as they affect the measurement of real product per man-hour, are discussed below.

Current Dollar Estimates. The principal method used to develop estimates of the value of final goods and services produced by the economy is the "commodity flow" method. This procedure involves starting with commodity output data at producers' prices, segregating for each commodity the portion of total output destined for final use and not requiring further processing; and then converting finished output at producers' prices to final costs to ultimate consumer by tracing the commodities through the various stages of the distributive system, i.e., adjusting for exports and imports, inventory change, transportation charges, and distributive markups.

The Census of Manufactures, with its vast commodity detail, is the basic source for the commodity flow approach. The census is available, however, for benchmark years only and estimates for the years in between are based on data, such as retail trade surveys, which are much less satisfactory from the viewpoint of estimating output of various categories of final goods and services.

For some categories of personal consumption expenditures for commodities, the commodity flow method is not considered feasible. These are estimated by multiplying quantities by average retail prices. The closeness of a value derived in this way to the actual value will depend upon the adequacy of the price data. If the commodity consists of several grades or styles, there may be a discrepancy unless a sufficient representation of the commodity is included in the calculations.

There are, in addition, those items which are part of the national output but do not enter into market transactions, such as food produced and consumed on farms. For these items values are imputed.

The Census of Business which collects data on the receipts of business establishments by types, i.e., laundries, beauty shops, automotive repair shops, etc., provides much of the basic data for personal consumption expenditures for services. In addition, other government agencies and private trade associations collect and publish data in the areas not covered by censuses, such as total revenues of firms engaged in transportation and utility businesses.

The allocation between consumer and business (intermediate) use of both commodities and services is sometimes troublesome because of the lack of reliable data for making such allocations. Frequently, the basis for the allocation is apparent from the nature of the commodity or service, or the published data show consumer and business consumption separately. However, in other cases, such as rail and air transportation, and gasoline, the basis for allocation is more difficult. Since possible errors in allocation affect the level of personal consumption expenditures, the level of GNP is also affected.

The Census data are supplemented by information obtained from other government agencies and trade associations, for estimating segments not covered by censuses. Supplemental data are used to estimate government purchases of goods and services, the value of new private construction, and net foreign investment.

For those components of GNP for which the censuses provide benchmarks, there is the problem of deriving estimates for years between censuses. The methods used in extrapolating the benchmark values have additional implications for the GNP per man-hour ratios because the available data are not generally as satisfactory as the benchmark data. In appraising the data for the intercensal period, it should be noted that these data are revised if necessary whenever Census data are published so the above discussion applies to the most recent non-Census periods.

For those components of GNP which are based on the non-Census data, there are fewer problems of extrapolation since whatever data are used are generally available on an annual basis.

As indicated previously, the year-to-year changes in personal consumption expenditures for commodities are estimated from the movement of retail sales. However, the retail sales data are collected by type of store rather than by commodities. This involves the assumption that purchases of a commodity move with total sales of a type of store, sales which include commodities other than the one under consideration. For example, stores whose principal business consists of appliances, and are therefore so classified, may sell appreciable quantities of furniture.

Business purchases of producer durable goods for much of the postwar period are estimated from manufacturers' shipments of these commodities as collected for the Census Annual Survey of Manufactures. This survey is based on a sample of establishments and is therefore subject to some sampling variation. In this area, the data are considered generally reliable.

Despite the limitations of both the retail sales and annual survey data, they have the advantage of being current value data, reflecting the current consumption pattern of consumers and businesses (final demand).

For some industries, particularly in the services group, neither current value data nor quantity data are available. The year-to-year change in the current value of personal consumption expenditures for these services is measured by the change in payrolls of the establishments providing the services as reported for unemployment insurance purposes. To assume that output moves with payrolls ignores the changes in other costs and profit margins and may not adequately reflect the changes in output per man-hour. This is the least satisfactory method of measuring output and is used only when no other data are available.

Constant Dollar Estimates. Constant dollar GNP is current GNP with the effect of price change removed. The desired constant dollar value is intended to be equal to current quantities of each commodity or service valued at constant (1954) prices. This valuation may be accomplished by dividing the current value of GNP by an appropriate index of price change. An alternative method of obtaining constant dollar GNP is actually to count the quantities of commodities consumed in each period and multiply them by the constant prices. Theoretically, the two methods should give the same results providing that the quantity data cover all the grades and qualities of the commodity that are reflected in differential prices. In practice, however, the two methods may not give the same result because the quantity data may not be available in sufficient detail to reflect possible shifts to greater demand for higher (or lower) quality of the commodity or the appropriate price indexes may not be available.

In actual practice, real GNP is derived largely by deflating the components of current value GNP. However, there are deviations from the concept caused by limitations of data which should be kept in mind in interpreting the output per man-hour ratios. These will be noted in the following summary of the procedures used by the Office of Business Economics in deriving constant dollar GNP.

The deflation procedure is carried out in considerable detail. For personal consumption expenditures, for instance, the number of separate estimates made is greater than the approximately 80 items shown in the published national income table on personal consumption expenditures. 3/

The price indexes used consist largely of the individual commodity indexes comprising the Bureau of Labor Statistics Consumer Price Index and Wholesale Price Index. These are supplemented by the U.S. Department of Agriculture Index of Prices Paid by Farmers, and indexes calculated from price information obtained from other government agencies and business sources.

3/ U.S. Department of Commerce, Survey of Current Business, National Income Supplement, 1954 and National Income Numbers, July 1956 and July 1957, table 30, and U.S. Income and Output, November 1958, table II-4.

Limitations of the Price Indexes. The Bureau of Labor Statistics price indexes are significant elements in the derivation of constant dollar GNP and also, as later described, net output for the manufacturing sector. The characteristics and limitations of these price indexes, as well as the solutions to other problems arising in the deflation procedure, affect both the level and movement of the deflated values.

The major problem is that the published price indexes do not cover all commodities and services included in the GNP. It is obviously not feasible to collect prices for every commodity in the economy. It follows that it is even less practical to collect prices for every grade, size, and style of a commodity. The price indexes therefore contain a large degree of imputation with the index of the specified commodity that is actually priced being considered representative of all the models and grades of that commodity. In addition, the index of the priced commodity is frequently imputed to many different commodities whose price movements are judged to be similar. While the extent of price imputation is known to be a weakness of the available price indexes, the direction of the error introduced by the underlying assumption is not known.

Furthermore, because it is generally impossible to express in commodity specifications certain qualitative aspects of goods priced, such as appearance or ease of operation, a commodity considered identical for price comparisons may actually change. If improvements in quality occur, with no change in the price, the consumer is in effect getting an improved article at the same price. When improvements in quality are not reflected in the price indexes, the deflated components of GNP are understated. Conversely, the exclusion of quality deterioration from the price indexes has the effect of overstating the deflated components of GNP.

Another weakness arises from the fact that actual prices paid may differ from the prices collected by BLS for the Wholesale Price Index, which is developed from reports of quoted prices. These are often list rather than actual prices. In times of material shortages, premiums paid by manufacturers may raise actual prices above the published price levels. In such circumstances, the price index would be understated and the deflated GNP overstated. When supplies are plentiful, discounts may be offered and paid prices may be lower than quoted prices with consequent overstatement of the price index and understatement of the deflated value. When either of these conditions is widespread and the differentials are measurable, some correction is generally applied. However, since there is generally a lag in recognition of the prevalence of price differentials, they continue to have an effect on the short-run changes in real GNP.

It must also be noted that the Consumer Price Index represents prices paid by moderate-income families and may not be representative of prices paid by other groups. Some adjustment for greater coverage is made in the deflation procedure by combining the CPI components with the U.S. Department of Agriculture's series of prices paid by farmers, but some purchasers are still

unrepresented. It is only if the overall price movement of the commodities purchased by these groups differs from that of the groups included that the change in the deflated values would be affected.

Other Aspects of the Deflation Procedure. Since the available price data are collected for other purposes, the product detail does not always coincide with the detail in which the components of GNP are estimated. The CPI, for instance, contains price indexes for several kinds of footwear and apparel, but personal consumption expenditures for footwear and apparel are estimated as product groups. It is therefore necessary to combine the CPI indexes with suitable weights to match the GNP product group. Theoretically, the weights should consist of the expenditures for each type of shoe and apparel in each year, but this is the very information which is lacking. Expenditure weights in the necessary detail are usually estimated for some base period from Census data and these fixed weights, rather than the desired current weights are used in combining the price indexes into product groups. If a change in the relative importance of the component commodities is associated with significantly different price movements, the fixed weighted price deflator may differ from the desired changing weight index.

For some commodities not directly priced for the CPI or WPI, indexes from other sources are used as deflators. These may be obtained from business sources, such as mail-order catalog prices or indexes maintained by mail-order houses. Or they are obtained from other Government agencies which collect price information for their own operations, such as the railway equipment cost index prepared by the Interstate Commerce Commission. These indexes are not always compatible with the theoretically desired deflated value, although there is not sufficient information concerning the manner in which they are prepared to evaluate them properly. In the case of imports and exports, the deflators are price indexes derived from value and quantity data for product groups rather than individual prices. Therefore, these deflators may not be strictly appropriate because they are subject to variation due to product mix within product groupings. In spite of conceptual limitations, the deflators have the advantage of being directly associated with the commodities to which they are applied. In this case, their use may yield better results than if CPI or WPI imputations were applied.

Use of Cost Indexes. For the construction sector, no direct price index is available. An attempt to approximate an index is made by pricing cost of materials and labor with some adjustment for changing profit margins. The major factor not taken into consideration in this estimation procedure is the possible change in productivity which would cause the movement of actual prices to deviate from the movement of the derived index. Since the output per man-hour of the construction sector has undoubtedly increased, the derived price index based on costs may be overstated, and as a result, the derived real product understated.

Count of Members of Organizations. In some cases, an index of quantities has been applied to the base year value to obtain constant dollar expenditures. This method is most frequently applied in those areas where the concept of the output of the service is such as to make accurate measurement impossible. How does one measure an increase in the real value of services performed by nonprofit organizations or schools? To count the members of an organization is to account for only one aspect of the volume of activity--it does not indicate whether services per member or pupil have expanded or declined. There are more pupils in schools, but if there are more pupils per teacher and other school services have been curtailed, the real output may not keep pace with the increase in the school population. Unfortunately, the difficulties involved in measuring these qualitative aspects make a count the only practical solution.

Use of Employment. For a few components, the movement of the constant dollar value is derived by deflating the current value by an index of average annual earnings or the base year value is moved directly by an index of employment or man-hours. The current values are generally those that have been estimated from the movement of payrolls and the same limitations of calculating output without regard to changes in output per man-hour applies. This is clear since with an increase in output per man-hour, output moves faster than employment, and with a decline, output moves more slowly than employment.

In addition, some of the current values derived from payroll data have been deflated by price indexes. While this is an improvement over deriving real product from the movement of employment, these cannot be considered deflated values since the assumption that current output moves with payrolls ignores the output per man-hour factor.

Major Sectors of the Economy

It has already been indicated that the gross national product for the economy is equal to the sum of GNP originating in the various sectors of the economy. The GNP originating in a sector or industry is, in turn, equal to the value of output minus the value of intermediate goods and services consumed. The value added or net output of the industry, when stated in constant dollars, is the "real" product of the sector or industry. Since the net output cannot be deflated directly, the real product is estimated by separately deflating the value of production and materials and services consumed and deriving a residual which implicitly measures the net output or value added in constant dollars. In the United States, estimates of real product consistent with this concept and methodology have been prepared for two major sectors; agriculture and manufacturing. The estimates for agriculture have been developed by the Office of Business Economics, U.S. Department of Commerce; estimates for manufacturing, by the Bureau of Labor Statistics, U.S. Department of Labor. These estimates have made it possible to derive additional subtotals for the total nonfarm economy and for total nonmanufacturing industries.

Agriculture. Estimates of real product originating in agriculture are developed and published by the Office of Business Economics. 4/

Agriculture real product is derived by deflating total agriculture output and total intermediate material and service inputs. The difference between the two deflated values is agriculture real product. The basic receipts and expenditure data are obtained from the Department of Agriculture but are adjusted to be consistent with the OBE concepts of real product. The total value of output includes: (1) cash receipts from farm marketings and Commodity Credit Corporation loans; (2) farm home consumption; (3) net changes in inventories; and (4) gross rental value of farm homes. The intermediate inputs cover such items as feed, fertilizer, seed, gasoline, insurance, veterinary service, etc. Payments for farm labor are not deducted as intermediate inputs since labor payments are part of the value added of the farm sector. Gross rents paid to nonfarm landlords are deducted since this represents part of the value added of nonagricultural sectors of the economy.

The detailed categories within total output and input are deflated by related price indexes, taken for the most part from the Department of Agriculture price data. The farm real product estimates developed by the Department of Commerce have been adjusted so far as possible for consistency with national income concepts and data, and are also in 1954 prices, consistent with the constant dollar GNP estimates.

Nonagricultural Sector. Private real product for the nonagricultural sector is equal to total private real product minus real product originating in the agricultural sector of the economy.

Manufacturing. Estimates of real product in manufacturing industries for the postwar period were based on the work of the Bureau of Labor Statistics in developing net output indexes for manufacturing industries. The net output measures were obtained by subtracting the cost of materials, parts, components, etc., in constant dollars from the constant dollar value of output (sales adjusted for changes in inventories). Previous indexes published by the BLS covering the years 1949-53 (1947=100) 5/ were revised and extended through 1957 by the same procedures. The estimate for 1948 was based on deflated gross output, since the detailed data for the computation of net output measures were not available for that year. The indexes for the years 1947-57 were applied to an estimate of real product originating in manufacturing in 1954 in order to obtain estimates of manufacturing real product for each year in 1954 dollars. A summary of the methods and sources for the manufacturing sector follows:

4/ Survey of Current Business, October 1958, table 7 (p. 13). For discussion of methodology, see September 1951 issue (p. 13).

5/ See Trends in Output per Man-Hour and Man-Hours per Unit of Output--Manufacturing, 1939-53 (BLS Report 100, 1955.)

1947-57. In estimating net manufacturing output for 1947 and 1949-57, the BLS utilized the data on dollar value of shipments, finished goods and goods-in-process inventories, and cost of materials for individual industries from the 1947 and 1954 Census of Manufactures and the Annual Surveys of Manufactures for 1949 through 1957. Published data from these sources were supplemented by unpublished tabulations and by special estimates. Totals for manufacturing cover virtually all of the approximately 450 Census industries.

The Census industry estimates cover the total activity of establishments classified in the industry. Data on value of shipments and costs of materials therefore relate both to primary products of the industry and to secondary products or items made primarily in other industries.

To correct annual 1947, 1949-57 data on value of shipments for price changes, indexes were specially constructed from the BLS wholesale price series. Price series for 1,800 specific products were classified by producing industry and combined into industry indexes. The commodities represented in the resulting industry index were those primary to the industry. Owing to the lack of readily available data on price movements of secondary products, prices of these were assumed to follow those for primary products. 6/ The weights used in combining product price indexes were based on value of shipments data from the 1947 Census of Manufactures.

An index of the prices paid for goods consumed by each industry was required to correct the annual value of materials consumed for price changes. The basis for constructing these cost deflators was the BLS interindustry chart 7/ showing the particular industries from which each industry purchased goods and services in 1947 and the actual value of such purchases. For the period 1947-56, cost deflators were constructed for each industry by combining the price indexes for supplying industries, derived in the manner described in the preceding paragraph, with weights based on the value of purchases in 1947 by the consuming industry. For 1957, the cost of materials was deflated at the total manufacturing level, rather than for individual industries. These adjustments were based on a special tabulation of the value of purchases by all manufacturing industries from each producing industry.

6/ As a test, 2 price indexes were prepared--1 in which individual price series were combined with total value of industry output (primary and secondary) as weights, and the other, in which the weights were the value of primary product, wherever made. The 2 indexes were practically identical.

7/ See summary tables (3 tables, 200-sector detail), Bureau of Labor Statistics, October 1952 (16 sections); see also article by W. Duane Evans and Marvin Hoffenberg, Interindustry Relations Study for 1947 (in Review of Economics and Statistics, Cambridge, Mass., May 1952, pp. 97-142).

To derive estimates more consistent with the net output concept and to improve their accuracy, several important adjustments of the data were made. First, estimates of the value of shipments (in constant dollars) were adjusted to include the constant dollar value of the net change in finished goods and goods-in-process inventories. Census data on beginning- and end-of-year book values of finished goods inventories for 1947 and 1950 to 1957 were deflated by industry price indexes as of the end of the year. Since separate annual data on goods-in-process inventories are not available prior to 1953, special estimates of these inventories were developed by applying ratios based on Office of Business Economics series on inventories, by stage of fabrication, to Census published totals of inventories of goods in process and materials. In addition, the cost of materials was adjusted at the total manufacturing level for changes in freight rates.

Although it is not possible to calculate precisely the margin of error of the net output index, a review of some factors affecting the reliability of the estimates provides some basis for a qualitative appraisal of the results.

The basic annual Census data on dollar value of shipments, inventories, cost of materials, and man-hours, collected by means of a sample survey, are subject to sampling error. For some industries, the sampling error is large, but for manufacturing as a whole, it is relatively insignificant. In addition, Census estimates are subject to errors of reporting to an unknown degree.

Other sources of error in net output estimates are the limitations of the price indexes used in deflating current dollar values. Since the price index used in constructing the net output series in base year prices was calculated with 1947 rather than given year quantity weights, the result approximates the theoretically correct series. BLS wholesale price indexes are based on quoted rather than actual prices and therefore may not be representative of the changes in monetary values embodied in the Census values. In constructing the index for deflating industry shipments, some error may be introduced because the price movements of a selected number of products may not be precisely representative of the movement of all products of the industry. In addition, the assumption that the prices of secondary products move as the prices of primary products may introduce into the industry estimates an error, which nevertheless is not considered to be significant for manufacturing as a whole.

In developing the material cost index, an index of average prices for a supplying industry was assumed to be representative of the particular product or group of products purchased from that industry by a consuming industry. Also, because of the lack of data, no account is taken of changes in trade margins.

Finally, since net output is calculated as the difference between gross output and materials consumed, for individual industries the error in this

difference may be larger than the error in the two totals from which it is derived. There is no reason to suppose, however, that any general bias is introduced by this procedure.

Index for 1948. The detailed value data required for calculating GNP for manufacturing for 1948 are not available since there was no annual survey in 1948. A gross measure was substituted for the desired net output index for this year. This was based on the deflation of manufacturers' sales, adjusted for change in inventories of finished products and goods in process. The data on manufacturing sales and inventories were from the published estimates of the Office of Business Economics, U.S. Department of Commerce. The adjusted sales at the total manufacturing level were deflated separately for total durables and nondurables and then combined with value added weights. The price deflators were special BLS price indexes for durable and nondurable manufactured products.

This gross measure differs from net output in that it is a duplicated output figure. It resembles the net output measure in that industry shifts are reflected but the change in the importance of industries is defined in terms of gross output, including purchases from other industries. However, the use of "value added" weights to combine the separate indexes for durables and nondurables brings the total manufacturing estimate somewhat closer to the net output measure.

Estimated 1954 GNP for Manufacturing. An estimate of GNP for the manufacturing sector for 1954 can be derived beginning with Census value added or national income originating in manufacturing. Each method requires different adjustments to conform to the concept, but the data necessary for making precise estimates are not available from these sources. However, one can arrive at a rough approximation of manufacturing GNP by using data obtained from other sources.

As was previously mentioned, Census value added differs from true net output 8/ in that the former includes some intermediate services and excludes some indirect business taxes. A rough adjustment was made by estimating Federal excise taxes originating in manufacturing, from Bureau of Internal Revenue data and estimating the intermediate services from data developed by BLS in the course of its study of interindustry relations.

National income originating in manufacturing differs from net output by the value of all indirect business taxes and the value of depreciation. An adjustment was made by deriving estimates of these values from BIR reports and BLS interindustry data.

8/ For definition of sector net output, see p. A-8.

It was not possible to complete the conceptual reconciliation of the Census based and National Income based figures, because of lack of data. A difference in the results was to be expected from the fact that the basic data are compiled from different sources with basic differences in concept. However, the difference was not very large and it was decided to accept as the final estimate a figure of $107 billion, the National Income based figure. Only the absolute GNP per man-hour is affected by this estimate. The index of GNP per man-hour in manufacturing remains the same regardless of this 1954 value of manufacturing net output.

Nonmanufacturing. The value of real product for the nonmanufacturing sector is a residual derived by subtracting manufacturing net output from private nonagricultural GNP. Therefore, any errors in the derivation of the farm and manufacturing real product estimates will be reflected in the nonmanufacturing sector.

Labor Input

General. As previously indicated, there is no one "official" series which measures aggregate labor input. Two series have therefore been developed for this report, one based primarily on Census Bureau data, the other based primarily on employment and hours data published by the Bureau of Labor Statistics. In concept, the former series covers hours worked; the latter covers hours paid. While neither series is completely adequate, each one may be useful in measuring output per man-hour.

The labor force estimates of the Census Bureau provide data on total persons engaged in production, covering all wage and salary employees, self-employed, and unpaid family workers. The same source provides data on average weekly hours worked by those at work. These estimates do not provide much detail, however, on the industrial composition of the labor force; the only hours distributions published for component sectors are agriculture and nonagriculture.

The lack of sector and industry detail in the Census labor force data is not a limitation from the viewpoint of estimating national output per man-hour, but it does represent an important limitation if the estimate at the national level is considered as providing the framework for estimates and analysis of output per man-hour for major sectors and industries. It provides, for example, little information on which to base an analysis of the effect of changes in the distribution of employment on aggregate output per man-hour.

In contrast to the limited detail of the Census labor force data, the Bureau of Labor Statistics estimates provide considerable detail on the industrial composition of wage and salary employees. They are, however, more limited in coverage than the labor force estimates. They do not cover agricultural employment, self-employed, and unpaid family workers. Domestics are also omitted from the BLS series. Estimates of average weekly hours are provided for most of the individual industries and sectors covered by the BLS, but there are significant gaps, particularly in finance and services and nonproduction

workers in manufacturing. In the estimates developed in this report, the BLS data have been supplemented from other sources in order to fill in gaps in hours and provide the additional coverage to make them more comparable to the labor force estimates. This has been done in order to arrive at an estimate for the total private economy (excluding general government) which would at the same time provide industrial detail for further analysis. The Bureau of Labor Statistics weekly hour estimates are based on the concept of hours paid, as distinguished from the hours worked concept of the Census data.

In addition to the differences in concept, another reason for developing two estimates is to provide a partial check on whether the trend indicated by one measure is roughly in line with the trend of the other measure. This is at best only a partial check since part of the data needed to supplement the BLS estimates are derived from unpublished labor force estimates. In addition, there are certain differences in coverage and definitions which would affect the comparison. It was felt, however, that in spite of these differences, the problems of obtaining accurate estimates of employment and hours of work from any one set of data was such that it would be desirable to obtain alternative estimates as a partial check on the estimated trend in total man-hours.

Bureau of the Census Labor Force Data

Description of Survey. The Census data on employment and hours of the civilian noninstitutional population were obtained from the Monthly Report on the Labor Force, one of the Current Population Survey reports. The data are based on the results of personal interviews during a particular week with a sample of the households throughout the country selected by scientific sampling methods. Prior to July 1955, the survey week was that which included the 8th of the month. This was changed to the week ending nearest the 15th of the month. Employment estimates here are based on a count of persons employed. A person holding more than one job is counted once in this survey.

In addition to the employment and hours estimates, data are obtained on the labor force, unemployment, and other economic characteristics. The following criteria are used for classifying persons on the basis of their activity.

Civilian Labor Force. The labor force comprises all civilians 14 years of age and over who are employed or unemployed.

Employed Persons. Employed persons comprise all those who, during the survey week, did any work at all as paid employees or in their own business or profession, or on their own farm, or who worked 15 hours or more as unpaid workers on a family farm or business, and those who were not working or looking

for work but who had jobs or businesses from which they were temporarily absent because of illness, vacation, bad weather, industrial dispute, or because they were taking time off for various other reasons.9/

Unemployed. The unemployed comprises all persons who did no work at all in the survey week and who were looking for work, or if not looking were temporarily ill or believed no work available in their line of work or in the community.

Hours Worked. The statistics on hours worked pertain to the actual number of hours worked during the survey week. For persons working in more than one job, these figures relate to the number of hours worked in all jobs during the week. Persons with jobs, but not at work during the survey week, are excluded from the computation of average hours worked.

Industry. The data on industry relate to the job held during the survey week. Persons employed at two or more jobs were reported in the job at which they worked the greatest number of hours during the week.

Adjustments to Data. Several adjustments were made to the basic Census data as published in the Monthly Report of the Labor Force. The agriculture data as published do not constitute a continuous series from 1947 to 1958, because of changes made in the estimating procedures in 1953, and the change from a 1940 to a 1950 population benchmark. These changes resulted in a considerable increase in the estimate of agricultural employment. To make the series for 1947-52 comparable with the agriculture data for the more recent years, an adjustment was made by applying the calculated increase in the employment estimates caused by the revisions, to the 1950-52 data, and prorating this increase backwards to 1947.

In the development of data for the private economy, it was also necessary to deduct estimates of general government employment. Since estimates of general government employees are not given in the Monthly Report of the Labor Force, data on Federal, State, and local employment other than government enterprises, taken from U.S. Income and Output, Table VI-14, 10/ were subtracted from the Census nonagricultural employment data.

The hours worked data were computed by multiplying annual average estimates of persons at work (as distinguished from persons employed) by average hours worked. In order to compute man-hours in agriculture, it was necessary

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9/ Effective January 1957, persons on layoff with instructions to return to work within 30 days of layoff and persons waiting to start new wage and salary jobs within the following 30 days are classified as unemployed. Such persons had been previously classified as employed (with a job but not at work). Estimates given in this report are consistent with the new definition.

10/ See Appendix F, Bibliography.

to adjust the published estimates of persons at work for the years 1947-52 for comparability with the published data for later years. The estimates of persons at work in agriculture were derived by taking the ratio of persons at work to total employed in the published series and applying this ratio to the adjusted agricultural employment series for 1947-52.

In computing the total man-hours in nonagricultural industries, a number of adjustments were required. The annual average of weekly hours worked, as published in the Monthly Report of the Labor Force, was adjusted to minimize the effects of the shortened workweeks in months in which legal and religious holidays occurred during the survey week. Since the data for the survey week are being used to represent the average for the month, the inclusion of data for holiday weeks creates a considerable error in the average hours data. Therefore, the average for each year was computed on the basis of nonholiday weeks.

Total hours in nonagricultural industries were computed by multiplying estimates of persons at work in nonagricultural industries by the adjusted average hours data. The private nonagricultural hours were derived by subtracting the hours in general government from this total. In order to derive the "at work" estimate for general government, it was first necessary to adjust the employment data for school employees, who are carried as employed during the summer months in the National Income Series, by assuming a 10-week vacation and multiplying their employment by 42/52. The sum of the adjusted school employment estimate and the Federal, State, and local other than school was then multiplied by 95 percent, assuming a 5-percent "not at work" rate--slightly higher than nongovernmental employees--for an estimate of persons at work in general government. In order to derive the government hours, the "at work" estimate was multiplied by the average hours in public administration from the Monthly Report of the Labor Force unpublished data and the total hours thus derived were subtracted from the total nonagricultural hours estimate.

In order to obtain an estimate of average weekly hours worked which could be related to the estimate of the number employed, as distinguished from the number at work, an adjusted average weekly hours estimate for each sector of the economy was derived by dividing the total man-hours for each sector by an employment estimate. Published Census data on average hours apply to persons at work only and do not include employed persons with a job but not at work, whether on paid or unpaid leave. The employment figure includes persons who did no work at all during a survey period, but who were classified by the Census Bureau as employed. The effect of this adjustment is to lower the average weekly hours to include the "zero" hours of the group of persons with a job but not at work. It does not, however affect the total hours.

Some Qualifications of Labor Force Data. Some labor force concepts should be kept in mind in evaluating the Census based measures of employment and hours. The labor force estimates include only workers 14 years of age and over and therefore exclude about 1 million workers under the age of 14 employed at farm jobs at certain seasons of the year, and about a half million at nonfarm jobs.

In addition, the Census method of counting a worker only once at his major activity, whether farm or nonfarm, and assigning the total number of hours worked to the major activity, may lead to an error in the estimate of agricultural versus nonagricultural hours.

Also to be considered in evaluating the data is the fact that the Census data are obtained through personal interviews with a sample of households, selected in accordance with a probability design, and are therefore subject to sampling errors, as well as errors in response and enumerative errors. The "response" or "enumerative" error may result in the missing of the part-time or marginal worker or the concentration of hours at the usual 40-hour workweek rather than at actual hours worked. The data are also limited by the adequacy of the information possessed by the respondent and the willingness to report accurately.

Bureau of Labor Statistics Employment and Hours Data

General Description. Estimates of employment and hours for the BLS based measure were obtained by use of the BLS nonagricultural employment and hours estimates supplemented by data from other sources. Published BLS estimates of nonagricultural employees by industry, and hours of workers were taken from the BLS Employment and Earnings reports. The BLS statistics are based on payroll records from a sample of establishments among which large establishments predominate. Changes from one month to the next in the employment reported by the sample respondents are applied to benchmark totals based primarily on unemployment compensation returns made by employers. The BLS employment series do not cover domestic workers, self-employed, or unpaid family workers; the weekly hours series do not cover certain additional categories. For purposes of this report, the excluded areas were estimated from other sources.

Weekly Hours and Total Hours. The BLS collects employment data for all sectors of the private nonfarm economy. Average hours data, on the other hand, are available for production workers in manufacturing and nonsupervisory workers in certain nonmanufacturing industries. In computing the total hours for industries except for manufacturing, the hours of supervisory employees were assumed to be the same as for nonsupervisory workers. Employees' hours were computed by multiplying estimates of employees by average hours of nonsupervisory workers for each industry. For manufacturing, since estimates of both production workers and production worker weekly hours are readily available from published reports, the hours estimates were computed by multiplying estimates of production workers by average hours and adding to this figure the hours of nonproduction workers derived by making an assumption that such persons work a 40-hour week. The average hours data, in this BLS type measure, refer not only to hours worked but, according to the BLS concept, additional hours paid for but not worked, such as paid sick leave, holidays, and vacations.

Supplementary Data. Since the BLS data are limited to nonfarm employees (excluding domestics), estimates for farm employment, nonfarm self-employed, unpaid family workers, and domestics were obtained from other sources. In addition, parts of the nonfarm average weekly hour estimates not covered by BLS were also supplemented by data from other sources. For example, average hours in the service industries and in finance and real estate were obtained from the Census Monthly Report of the Labor Force unpublished series.

The Census Monthly Report of the Labor Force series was also the source for estimates of agricultural employment and hours. In computing hours worked, average hours data were applied to estimates of persons "employed" instead of "at work," for comparability with the BLS concept of hours worked or paid. By using the employed figure, an implicit assumption was made that persons who held farm jobs, but were absent from work, were paid. The same procedure was used to approximate hours paid in other instances where Census data on weekly hours were used to supplement BLS data, e.g., services, finance, real estate, etc.

Although the BLS statistics cover government employment, separate data are not shown for government enterprises which sell their "product" (Post Office, TVA) and are therefore considered in the National Income framework to be part of the private economy. For this series, the estimates of employees of government enterprises as shown in the National Income Supplement and the average hours of public administration workers from the Monthly Report of the Labor Force were used as part of the estimate of total private man-hours.

Estimates of active proprietors in unincoprorated enterprises were taken from the National Income Supplement and were derived by subtracting the full-time equivalent employees from the total number of persons engaged in production, by industry. Estimates of the number of domestics were also obtained from the same source. The average hours for these groups were obtained from unpublished Census data on hours worked.

Unpaid family workers included in this measure are persons working without pay in family business for 15 hours or more during the week. The estimates of number of persons and the average hours worked were taken from the Census Monthly Report of the Labor Force.

In evaluating the data, it is important to keep in mind that assumptions and imputations have been made, and data have been used from different sources, based on different concepts. In all, for the year 1955, one-fourth of the total employment figure in the BLS based measure was taken from sources other than BLS, and the hours of one-half of the employees were either obtained from other sources or imputed from other BLS data. Of the nonfarm employee total (i.e., excluding farm, self-employed, and unpaid family workers), only 7 percent of employment was derived from other sources, and the hours of one-third of the employees were either imputed from other BLS data or came from other sources.

Table A-1. Employment, man-hours, real product, real product per man-hour, and hours paid per dollar of real product, 1947-58

(Man-hour estimates based primarily on Bureau of Labor Statistics data)

	Item	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
	Employment (thousands):												
1.	Total private	55,070	55,769	54,581	55,632	57,639	58,241	59,055	57,582	59,829	61,377	61,232	59,048
2.	Agriculture	8,490	8,227	8,318	7,831	7,382	7,126	6,555	6,495	6,718	6,572	6,222	5,844
3.	Nonagricultural industries	46,580	47,542	46,263	47,801	50,257	51,115	52,500	51,087	53,111	54,805	55,010	53,204
4.	Manufacturing	15,481	15,504	14,363	15,161	16,305	16,539	17,440	16,188	16,748	17,090	16,967	15,650
5.	Nonmanufacturing	31,099	32,038	31,900	32,640	33,952	34,576	35,060	34,899	36,363	37,715	38,043	37,554
	Average weekly hours:												
6.	Total private	42.9	42.6	42.1	42.1	42.0	41.9	41.7	41.3	41.5	41.2	40.6	40.3
7.	Agriculture	50.6	50.3	49.4	48.7	49.2	48.7	49.3	48.4	47.7	46.7	45.6	45.2
8.	Nonagricultural industries	41.5	41.3	40.8	41.0	41.0	41.0	40.7	40.4	40.7	40.5	40.1	39.7
9.	Manufacturing	40.4	40.2	39.5	40.5	40.6	40.7	40.5	39.9	40.6	40.4	39.9	39.5
10.	Nonmanufacturing	42.1	41.8	41.4	41.2	41.1	41.1	40.9	40.7	40.7	40.6	40.2	39.8
	Annual man-hours (billions):												
11.	Total private	122.9	123.6	119.4	121.7	126.0	127.0	128.0	123.7	129.1	131.5	129.4	123.7
12.	Agriculture	22.3	21.5	21.4	19.8	18.9	18.0	16.8	16.3	16.7	16.0	14.8	13.7
13.	Nonagricultural industries	100.6	102.1	98.1	101.9	107.1	108.9	111.2	107.4	112.4	115.5	114.7	110.0
14.	Manufacturing	32.6	32.4	29.5	31.9	34.5	35.0	36.7	33.6	35.4	35.9	35.2	32.1
15.	Nonmanufacturing	68.1	69.7	68.6	69.9	72.6	73.9	74.5	73.8	77.0	79.6	79.4	77.8
	Gross national product (billions of 1954 dollars):												
16.	Total private	259.6	270.3	268.7	293.3	311.1	320.4	336.2	330.8	360.4	368.2	375.1	365.5
17.	Agriculture	16.9	19.3	18.3	19.3	18.1	18.8	19.5	20.3	21.4	20.9	20.6	21.7
18.	Nonagricultural industries	242.7	251.0	250.4	274.0	293.0	301.6	316.7	310.5	339.0	347.3	354.5	343.8
19.	Manufacturing	86.3	88.1	82.1	95.0	104.1	107.3	118.1	107.0	120.8	124.0	122.3	(1/)
20.	Nonmanufacturing	156.4	162.9	168.3	179.0	188.9	194.3	198.6	203.5	218.2	223.3	232.2	(1/)
	Real product per man-hour:												
21.	Total private	2.11	2.19	2.25	2.41	2.47	2.52	2.63	2.67	2.79	2.80	2.90	2.95
22.	Agriculture	.76	.90	.86	.97	.96	1.04	1.16	1.24	1.28	1.31	1.40	1.58
23.	Nonagricultural industries	2.41	2.46	2.55	2.69	2.74	2.77	2.85	2.89	3.02	3.01	3.09	3.13
24.	Manufacturing	2.65	2.72	2.79	2.97	3.02	3.07	3.22	3.19	3.41	3.45	3.47	(1/)
25.	Nonmanufacturing	2.30	2.34	2.45	2.56	2.60	2.63	2.67	2.76	2.83	2.80	2.92	(1/)
	Hours paid per dollar of real product:												
26.	Total private	.47	.46	.44	.42	.41	.40	.38	.37	.36	.36	.35	.34
27.	Agriculture	1.32	1.11	1.17	1.03	1.04	.96	.86	.81	.78	.76	.72	.63
28.	Nonagricultural industries	.41	.41	.39	.37	.37	.36	.35	.35	.33	.33	.32	.32
29.	Manufacturing	.38	.37	.36	.34	.33	.33	.31	.31	.29	.29	.29	(1/)
30.	Nonmanufacturing	.44	.43	.41	.39	.38	.38	.38	.36	.35	.36	.34	(1/)

1/ Not available.

Notes to table A-1

Line 1. Line 2 plus line 3.

Line 2. The 1953-58 data from the Census Bureau, Current Population Reports, Labor Force. Due to a change in the estimating procedure, the 1947-52 data from the source mentioned above have been adjusted for comparability with the more recent series.

Line 3. Sum of line 4 and line 5.

Line 4. Derived by supplementing the estimates of employees in manufacturing from the BLS Employment and Earnings report with estimates of active proprietors in unincorporated manufacturing businesses from the U.S. Department of Commerce, Office of Business Economics, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958.

Line 5. Derived by supplementing the BLS estimates of employees in nonmanufacturing industries, excluding government, with estimates of unpaid family workers from the Census Bureau's Current Population Reports, Labor Force, and estimates of domestics, active proprietors of unincorporated nonmanufacturing businesses, and employees of government "enterprises" from the U.S. Department of Commerce, Office of Business Economics, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. The 1958 figure is a BLS estimate.

Line 6. Derived as a weighted average of average weekly hours in agriculture and nonagricultural industries.

Line 7. From the U. S. Department of Commerce, Bureau of the Census, Current Population Reports, Labor Force.

Line 8. Derived as a weighted average of manufacturing and nonmanufacturing average weekly hours.

Line 9. Obtained as a weighted average of weekly hours of employees and of active proprietors in manufacturing. Source of average weekly hour information: Bureau of Labor Statistics, supplemented by Bureau of the Census unpublished labor force data.

Line 10. Obtained as a weighted average of weekly hours of nonmanufacturing employees (including domestics and employees of government "enterprises"), proprietors and unpaid family workers. Source of average weekly hours information: Bureau of Labor Statistics supplemented by Bureau of the Census unpublished labor force data.

Notes to table A-1--Continued

Line 11. Sum of line 12 and line 13.

Line 12. Line 2 times line 7 times 52 weeks.

Line 13. Line 3 times line 8 times 52 weeks.

Line 14. Line 4 times line 9 times 52 weeks.

Line 15. Line 5 times line 10 times 52 weeks.

Line 16. U.S. Department of Commerce, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. 1958 figure estimated by the Office of Business Economics.

Line 17. U.S. Department of Commerce, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. The 1958 figure from the Survey of Current Business, February 1959

Line 18. Line 16 minus line 17.

Line 19. 1947 and 1949-56 BLS revisions and extensions of estimates published in BLS Report 100. 1948 and 1957 extensions estimated by BLS from deflated U.S. Department of Commerce, Office of Business Economics value data.

Line 20. Line 18 minus line 19.

Line 21. Line 16 divided by line 11.

Line 22. Line 17 divided by line 12.

Line 23. Line 18 divided by line 13.

Line 24. Line 19 divided by line 14.

Line 25. Line 20 divided by line 15.

Line 26. Line 11 divided by line 16.

Line 27. Line 12 divided by line 17.

Line 28. Line 13 divided by line 18.

Line 29. Line 14 divided by line 19.

Line 30. Line 15 divided by line 20.

Table A-2. Labor force, employment, man-hours, real product per man-hour and hours worked per dollar of real product, 1947-58

(Man-hour estimates based primarily on Bureau of the Census labor force data)

	Item	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958
1.	Total labor force (thousands).....	61,992	63,165	64,022	65,083	66,316	66,894	67,362	67,818	68,896	70,387	70,744	71,284
2.	Armed Forces.....	1,590	1,456	1,616	1,650	3,098	3,594	3,547	3,350	3,048	2,857	2,797	2,637
3.	Civilian labor force.....	60,402	61,709	62,406	63,433	63,218	63,300	63,815	64,468	65,847	67,530	67,946	68,647
4.	Unemployed.....	2,356	2,325	3,682	3,351	2,099	1,932	1,870	3,578	2,904	2,822	2,936	4,681
5.	Employed.....	58,046	59,384	58,724	60,082	61,118	61,369	61,945	60,890	62,944	64,708	65,011	63,966
6.	Government civilian-general	4,963	5,129	5,316	5,471	5,847	6,042	6,092	6,181	6,420	6,712	6,932	7,175
7.	Total private.....	53,083	54,255	53,408	54,611	55,271	55,327	55,853	54,709	56,524	57,996	58,079	56,791
8.	Agriculture.....	8,490	8,227	8,318	7,831	7,382	7,126	6,555	6,495	6,718	6,572	6,222	5,844
9.	Nonagricultural industries	44,594	46,027	45,090	46,780	47,889	48,201	49,298	48,214	49,805	51,424	51,857	50,947
	Average weekly hours:												
10.	Total private.....	42.3	41.9	41.4	41.0	41.2	41.1	40.9	40.1	40.4	40.0	39.5	39.0
11.	Agriculture.....	48.9	48.6	48.2	47.3	47.9	47.3	48.0	47.1	46.4	45.4	44.2	43.7
12.	Nonagricultural industries....	41.0	40.7	40.2	40.0	40.2	40.1	40.0	39.2	39.6	39.3	38.9	38.4
	Annual hours per employee:												
13.	Total private.....	2,199	2,176	2,154	2,134	2,142	2,135	2,128	2,086	2,099	2,081	2,052	2,026
14.	Agriculture.....	2,545	2,525	2,505	2,457	2,489	2,463	2,494	2,447	2,412	2,362	2,297	2,270
15.	Nonagricultural industries....	2,133	2,114	2,090	2,080	2,089	2,087	2,079	2,038	2,057	2,046	2,022	1,998
	Man-hours (billions):												
16.	Total private.....	116.7	118.1	115.1	116.5	118.4	118.1	118.8	114.1	118.6	120.7	119.2	115.0
17.	Agriculture.....	21.6	20.8	20.8	19.2	18.4	17.6	16.4	15.9	16.2	15.5	14.3	13.3
18.	Nonagricultural industries....	95.1	97.3	94.2	97.3	100.0	100.6	102.5	98.2	102.4	105.2	104.9	101.8
	Gross national product (billions of 1954 dollars):												
19.	Total private.....	259.6	270.3	268.7	293.3	311.1	320.4	336.2	330.8	360.4	368.2	375.1	365.5
20.	Agriculture.....	16.9	19.3	18.3	19.3	18.1	18.8	19.5	20.3	21.4	20.9	20.6	21.7
21.	Nonagricultural industries....	242.7	251.0	250.4	274.0	293.0	301.6	316.7	310.5	339.0	347.3	354.5	343.8
	Real product per man-hour:												
22.	Total private.....	2.22	2.29	2.34	2.52	2.63	2.71	2.83	2.90	3.04	3.05	3.15	3.18
23.	Agriculture.....	.78	.93	.88	1.00	.99	1.07	1.19	1.28	1.32	1.35	1.44	1.64
24.	Nonagricultural industries....	2.55	2.58	2.66	2.82	2.93	3.00	3.09	3.16	3.31	3.30	3.38	3.38
	Hours worked per dollar of real product:												
25.	Total private.....	.45	.44	.43	.40	.38	.37	.35	.35	.33	.33	.32	.31
26.	Agriculture.....	1.28	1.08	1.14	1.00	1.02	.93	.84	.78	.76	.74	.69	.61
27.	Nonagricultural industries....	.39	.39	.38	.36	.34	.33	.32	.32	.30	.30	.30	.30

Notes to table A-2

Line 1. Source is Current Population Reports, Labor Force, Bureau of the Census, U. S. Department of Commerce. Due to a change in the estimating procedure, the 1947-52 labor force data have been adjusted for comparability with the more recent series. The 1953-58 data are from the Labor Force Reports as published.

Line 2. From the Economic Report of the President, January 1958, table F-17 (p. 135).

Line 3. Same as line 1.

Line 4. From the Labor Force Reports.

Line 5. Same as line 1.

Line 6. Computed as the sum of general government employees, Federal, State and local other than the military, excluding employees in government enterprises from the U.S. Department of Commerce, Office of Business Economics, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. The 1958 figure is a BLS estimate based on OBE data.

Line 7. Line 5 minus line 6.

Line 8. Same as line 1.

Line 9. Line 7 minus line 8.

Line 10. Derived as the weighted average of hours in agricultural and non-agricultural industries.

Line 11. Based on labor force data, adjusted to reflect zero hours of work for those employed, but not at work.

Line 12. Based on labor force data, adjusted as follows: (1) to reflect "zero" hours of work for persons with a job but not at work, (2) to minimize the effects of holidays on average hours, and (3) to exclude hours of general government employees.

Line 13. Line 10 times 52 weeks.

Line 14. Line 11 times 52 weeks.

Line 15. Line 12 times 52 weeks.

Notes to table A-2--Continued

Line 16. Line 7 times line 13.

Line 17. Line 8 times line 14.

Line 18. Line 9 times line 15.

Line 19. From the U.S. Department of Commerce, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. 1958 estimates by the Office of Business Economics.

Line 20. From the U.S. Department of Commerce, U.S. Income and Output, A Supplement to the Survey of Current Business, 1958. The 1958 figure from the Survey of Current Business, February 1959.

Line 21. Line 19 minus line 20.

Line 22. Line 19 divided by line 16.

Line 23. Line 20 divided by line 17.

Line 24. Line 21 divided by line 18.

Line 25. Line 16 divided by line 19.

Line 26. Line 17 divided by line 20.

Line 27. Line 18 divided by line 21.

Table A-3. National income and product account, 1957

(Billions of current dollars)

Charges against gross national product		Expenditures of gross national product	
Compensation of employees	254.6	Personal consumption expenditures	284.4
Income of unincorporated enterprises and inventory valuation adjustment	43.0	Gross private domestic investment	65.3
Rental income of persons	11.8	Net foreign investment	3.5
Corporate profits and inventory valuation adjustment	41.9	Government purchases of goods and services	87.1
Corporate profits before tax	43.4		
Corporate profits tax	21.6		
Corporate profits after tax	21.8		
Dividends	12.4		
Undistributed profits	9.4		
Inventory valuation adjustment	-1.5		
Net interest	12.6		
National income	364.0		
Indirect business tax and non-tax liability	37.6		
Business transfer payments	1.6		
Statistical discrepancy	0.7		
Less: Subsidies minus current surplus of government enterprises	1.3		
Charges against net national product	402.6		
Capital consumption allowances	37.7		
Gross national product	440.3	Gross national product	440.3

Source: U.S. Department of Commerce, Survey of Current Business, July 1958.

Table A-4. Gross national product and major components in current and constant dollars, and implicit price deflators, 1954 and 1957

(Billions of dollars)

Item	1954 (1954 $)	1957 (1957 $)	1957 (1954 $)	Implicit price deflator 1957 (1954=100)	Change in physical volume (1954=100)
Gross national product....	363.1	440.3	407.1	108.2	112.1
Personal consumption expenditures.....	238.0	284.4	270.3	105.2	113.6
Durable goods.....	32.4	39.9	38.1	104.7	117.6
Nondurable goods.....	119.3	138.0	132.7	104.0	111.2
Services.....	86.3	106.5	99.4	107.1	115.2
Gross private domestic investment.....	48.9	65.3	57.8	—	118.2
New construction.....	29.7	36.5	32.3	112.9	108.8
Residential nonfarm	15.4	17.0	15.5	110.1	100.6
Other.....	14.3	19.5	16.9	115.5	118.2
Producer durable equipment.....	20.8	27.9	24.1	115.8	115.9
Change in business inventories.....	-1.6	1.0	1.4	—	—
Net foreign investment..	-0.4	3.5	2.6	—	—
Government purchases of goods and services....	76.6	87.1	76.2	114.3	99.5
Federal.....	48.9	50.8	43.9	115.7	89.8
State and local.....	27.7	36.3	32.3	112.4	116.6
Addendum:					
Gross government product 1/.....	32.3	38.6	33.2	116.4	102.8
Total private gross product.....	330.8	401.7	373.8	107.5	113.0

1/ Wages and salaries of general government employees.

Source: U.S. Department of Commerce, Survey of Current Business, July 1958.

Note: Because of rounding, sums of individual items may not equal totals.

Appendix B. Comparison of Census and Bureau of Labor Statistics Man-Hour Measures in the Total Private Economy

Because of the difference in survey methods and concept, the BLS type measure shows both a higher employment estimate and a higher total man-hour and average weekly hours estimate than the Census based measures. (See tables A-1 and A-2.)

Employment

The counting of jobs rather than persons is perhaps the main reason for the higher employment estimate. As in the cases of multiple job holders and in job turnover, 1 person may, during a survey period, be on more than 1 payroll. According to a Census Survey on work experience of the population, about 3.5 million persons in 1957 had 2 or more jobs simultaneously. 1/ Also, the BLS data include children under 14 working on nonfarm jobs who are on payrolls, whereas they are not included in the Census type count. On the other hand, the Census data include as employed a number of persons who have jobs but are not at work an entire week and are not on paid status--groups not included in the BLS employment count.

Weekly and Total Hours

The inclusion of hours paid but not worked in the BLS based measure is the principal reason for the higher man-hour estimate in this series. Differences in survey methods in the two series, counting of persons versus counting of jobs, should have no effect on the total man-hours data. In the case of either multiple jobs or job turnover, the BLS series would count payroll hours on each job; the Census would count total hours worked.

Estimates of average weekly hours of all employed persons, in the Census based measure, are lower than those in the BLS, partly because of the inclusion of all persons with a job but not at work (the "zero" hours worked group) in the computation. If, however, average hours of persons "at work" were to be compared with the BLS data, this estimate would be considerably higher, since Census would count total hours worked by persons with two or more jobs and BLS the hours on each job.

1/ U.S. Department of Commerce, Bureau of the Census, Current Population Reports, Labor Force, Multiple Job Holding, July 1957. Series P-50, No. 80, February 1958.

Problems of Using Weekly Sample

Another probable cause for some of the discrepancy between the BLS and Census labor force based measures is due to the exaggerated effect of holidays, bad weather, or unusual events occurring during the survey week. For both the BLS and the Census based measures, a specified payroll period or survey week 2/ has been taken to represent a month, so that lower weekly hours due to holidays or other reasons are reflected as lower average weekly hours for the month. The BLS based measure, however, would reflect only unpaid hours off; the Census, all hours off.

Because the event of a legal or religious holiday during a survey week results in a considerable decrease in the average workweek as measured by Census, an adjustment has been made in computing annual hours worked to minimize the effect of holidays. It should be noted that few, if any, legal holidays occur in the survey week used by Census and the BLS programs. If the incidence of time off the job because of legal or religious holidays has increased during the postwar period, the exclusion of the holiday weeks, plus the fact that very few are picked up in the survey week, would lead to an upward bias in the man-hours worked index and therefore a downward bias in the output per man-hour estimates based on hours worked.

The use of a weekly sample to represent the month in both the BLS and Census labor force based measures may also lead to some error in the estimate of total man-hours due to the lost time resulting from strikes. If the strikes occur during the survey week, this may exaggerate the effect of lost time and lead to an underestimate of man-hours for the month as a whole. On the other hand, if the strikes occur in weeks of the month other than the survey week, this may lead to an overestimate of man-hours for the month.

In this case, in contrast to the adjustment mentioned above for legal holidays in the Census labor force data, no adjustment is made because adequate data are not available. It is believed, however, that the incidence of strikes follows no particular pattern and is presumed to be randomly distributed throughout the month.

The random distribution of strikes implies that from the viewpoint of the problem of using the weekly sample as representative of the month, the underestimates and overestimates cancel each other and the estimated total is approximately correct. Legal holidays, on the other hand, fall on certain days each year and are therefore not randomly distributed.

2/ BLS--Payroll periods ending nearest the 15th of the month. Census labor force--Beginning July 1955, labor force data are for the calendar week ending nearest the 15th of the month; previously, the week containing the 8th.

Agriculture

The man-hour measures for the agricultural sector of the economy developed for this report are based on the Census labor force data. Two measures were prepared for the agricultural sector; one based on hours "worked," the other on hours "paid," including hours worked of unpaid family workers. Both measures were based on the Census labor force data. The only difference between the two was a minor adjustment in the latter measure to include the hours of those with a job but not at work on the assumption that they were paid.

As previously noted in the section on trends, the measures for the agricultural sector used in this report reflect "actual" hours and cover men, women, and children 14 and over. This estimate of "man-hours" differs from the Department of Agriculture estimate in which all hours are estimated in terms of equivalent adult male hours required for agricultural production. The Census based estimate was used in this report in order to develop measures for the sectors and total private economy that could be consistent with the "actual" man-hours used for nonagricultural sectors.

Nonagriculture

The estimate for nonagricultural man-hours based on Census data was obtained by multiplying the employment by average hours for that sector and making adjustment for holidays and the hours of general government employees.

The man-hour measure based primarily on Bureau of Labor Statistics data was obtained by summing the estimates for each of the nonagricultural sectors, including the additional categories of self-employed, unpaid family workers, and domestics.

Manufacturing

The man-hours paid estimate was based primarily on the BLS data covering manufacturing employment and average weekly hours of production workers. The average weekly hours of nonproduction workers was assumed to be 40 hours a week during the postwar period. The estimate of proprietors in manufacturing industries was obtained from the National Income data. The estimate of average weekly hours of proprietors was obtained from unpublished Census labor force data. It was assumed that the number of unpaid family workers in manufacturing was quite small and therefore no additional estimate for this category was made.

Nonmanufacturing

The man-hours paid estimate was based primarily on BLS employment and average weekly hours data for the component sectors and industries. Separate estimates were prepared for each sector or industry and then summed to arrive

at a total man-hours paid estimate for all private nonfarm, nonmanufacturing industries. Supervisory employees were assumed to work the same hours as those whom they supervised. The estimates for proprietors and domestics were based on the National Income data. Information on nonfarm unpaid family workers and average weekly hours of proprietors, service, banking, and insurance employees was obtained from unpublished Census labor force data.

Appendix C. Comparability of Real Product and Man-Hour Estimates

Comparability of output and labor input parts of the ratio is one of the major problems in productivity measurement, since, with few exceptions, the estimates for the related output and man-hours are obtained from different sources of data. Comparability of coverage is more of a problem at the industry level, but this diminishes as the activity being measured is expanded to cover major industry groups and sectors of the economy. The problem is minimized when the productivity measure relates to the total private economy. There are still some problems of comparability remaining, however, even for the total private economy and major sectors shown in this report. The more important problems of consistency of coverage are discussed in this section, starting with those relating to the total private economy, followed by a similar analysis for each of the major sectors.

Total Private Economy

Measure Limited to Private Economy. At the total private economy level, most of the problems of comparability found at lower levels of aggregation are avoided, even though the estimates of real product and man-hours are obtained from different sources. As previously indicated, the major adjustment at this level is the subtraction of the man-hours of general government employees from the total man-hour measure based on the Census labor force data, in order to ensure comparability with the estimates of private gross national product.

Effect of Imputations to Gross National Product. A significant discrepancy between man-hours and GNP would exist were it not for the practice of imputing values in GNP for certain types of transactions which are not monetary in form but nevertheless represent a flow of goods or services with a corresponding labor input. For example, a value is imputed for food produced and consumed on farms. The man-hours data for agriculture cover total product. If the imputation were not included, output per man-hour would be understated. The same is true of other imputations, such as food and clothing furnished military personnel and services performed by banks without explicit charge. The man-hours involved in these goods and services are included in total man-hours and the imputation is needed to account for the corresponding output.

Sometimes, however, an imputation has the opposite effect on the output-input relationship. One of these imputations is the rental value of owner-occupied homes. In the estimate of GNP the value of owner-occupied homes is treated as though the homes were rented. For homes that are actually rented, employment involved in managing and maintaining the property is reflected in the employment of the real estate industry. However, it is not possible to calculate the employment involved in management and maintenance performed by home owners. The output per man-hour ratio is therefore overstated. If the

proportion of the value of owner-occupied homes to the value of rented homes remained constant, this overstatement would be the same in each period and there would be no effect on the movement of private real product per man-hour. Although there has been an increase in the proportion of owner-occupied homes, our estimate of the effect of this factor on total private productivity indicates that the exclusion of imputed rents from the total private real product in order to ensure comparability would not result in modifying the overall productivity measure to any significant extent.

Income From Abroad. Another instance of nonmatching man-hours and GNP results from the fact that the value of GNP includes the value of "output not produced in the United States but accruing to U. S. residents." For the purpose of calculating output per man-hour ratios, the deflated value of this item should be subtracted so that the domestic employment is related to domestic GNP.

Fortunately, this item is a relatively small amount in the United States economy and here again a rough estimate for this factor indicated that although the level of output per man-hour might be slightly overstated due to this lack of comparability, it would have little effect on the trend in output per man-hour for the total private economy.

Production and Labor Input of Children Under 14. It has been previously indicated that the Census labor force estimates exclude children under 14. This exclusion does not hold for the employment data of the Bureau of Labor Statistics and Census of Manufactures and Annual Surveys of Manufactures which include all persons on the payroll, regardless of age. It is estimated that there are approximately a million children under 14 years of age working on farm jobs at certain seasons of the year and somewhat less than 1/2 million in nonagricultural industries. There is relatively little information on the trend in this group of workers in relation to the growth in the labor force but, since the under 14 group is found primarily in the farm sector and the employment in this sector has been steadily decreasing over the years, it is quite probable that the omission of the under 14 group from labor force estimates tends to overstate the increase in man-hours during the postwar years and understate output per man-hour.

The lack of comparability in the previous three items--imputed rent, income from abroad, and output of children under 14--has been due to the inclusion of these items in GNP without corresponding labor inputs. The opposite situation exists in the case of the next group of items, where the labor input is not matched by corresponding value of output.

Research and Development. The treatment of research and development activities not connected with current production presents a rather complex conceptual and statistical problem from the viewpoint of productivity measurement. At the present time, private research and development activities are not included as a separate item in GNP. In the national income system of accounts, private research and development expenditures,

which are written off as current costs, are considered to be "intermediate" costs and their value added is assumed to be included in the value of some part of final goods and services. In theory, the research and development expenditures which are capitalized should be included as part of GNP just as expenditures for new plant and equipment are included. In practice, it is extremely difficult to obtain any data on such capitalized research and development expenditures, and such expenditures are therefore not included in GNP. The current treatment of research and development expenditures presents a problem because the labor input associated with these activities is included in the current man-hours of the economy and sector where the activity takes place. However, the "output," as distinguished from the accounting conventions, may not be reflected until many years later, if at all. The problem is in part analogous to that presented by the measurement of output per man-hour for those categories of products, such as aircraft, shipbuilding, turbines and generators, which take many months and years to complete and the output in any given year is usually defined in terms of work "put in place" rather than completed products.

This problem is of some concern due to the increasing resources being devoted to research and development activities and the possibility that this increase may account in part for the increasing proportion of "nonproduction" workers, particularly in manufacturing. There is no satisfactory method of "adjusting" the measure of output per man-hour to take account of the increase in these activities, but this factor should be kept in mind in evaluating the trend in output per man-hour.

Agriculture Versus Nonagriculture

The estimate of agricultural man-hours used in this report is based on the Census labor force data. Consistent with the labor force definitions, persons employed at two or more jobs are reported in the job at which they worked the greatest number of hours. The man-hours of persons whose principal occupation is farming but who also have secondary jobs in nonagricultural industries are, therefore, all included under farming. Conversely, the man-hours involved in farming as a secondary activity of those whose principal occupation is in nonagriculture are included in the latter category. The available evidence, limited to Census labor force studies for July of 1946, 1950, 1956, and 1957, indicates that the errors are offsetting and that on net balance, there is no bias in the change in agriculture man-hours. It should be stressed that these studies are not conclusive evidence since they cover only the July months of a few years, and July may be a poor month for the purpose of testing the extent of error for the agricultural sector.

Appendix D. Limitations and Qualifications of Output Per Man-Hour Measures

In evaluating or using the output per man-hour measures given in this report, there are a number of general limitations and qualifications which should be kept in mind. Most of these have already been mentioned throughout this report. For convenience, the general qualifications and limitations are summarized in this section.

The first point to be emphasized is that the limitations of available data make it difficult to construct precise measures of output per man-hour. The measures should, therefore, be regarded as general indicators of output per man-hour trends, rather than precision instruments. As such they are useful in studying the economy and its growth, in evaluating the technological progress of industry, and in understanding the employment implications of the changing relationships between output and manpower requirements.

Some of the more important data limitations may be summarized as follows:

1. Output and man-hour data are inadequate or provide only partial coverage for some industries or categories. In other areas, price data needed for deflating the value of output are inadequate due to lack of coverage or appropriate weights consistent with the requirements of the deflation procedure. These data limitations require imputations that may lead to errors in the resulting measures which cannot be checked directly, because the very data needed to make the correct adjustments in the first instance are needed for testing the extent of the error. A partial and indirect check on the trend of the man-hour part of the output per man-hour ratio can be inferred from the fact that the two man-hour measures developed for this report are in reasonably close agreement, after taking account of the differences in concept.

In addition, more work and data are needed to develop separate estimates of real product for the nonmanufacturing sectors, which are included in this report as a residual estimate. Independent estimates would be useful in providing additional information on trends for components of the total economy and would also provide a partial check on the estimate for the total private economy and the residual estimate for total nonmanufacturing.

2. Existing data and techniques do not provide for a full accounting of the continuing changes in the quality of goods and services produced. To a limited extent, identifiable changes in product specifications are taken into account in the real product and output per man-hour indexes. In many cases, however, specification and quality changes are not reported. In other instances, quality change is so intangible that it cannot be measured with existent techniques. To the extent that, over the long run, quality is improving, the indexes of

output per man-hour are understated. It should be noted that this problem of quality change characterizes all existent production measures and many other statistics as well.

3. Quite often there are problems of consistency and comparability between the methods used to estimate output and those used to estimate labor input. These tend to occur most often at finer levels of industry detail; but are minimized at higher levels of aggregation.

4. For many activities, e.g., services, construction, finance, research, households, and nonprofit institutions that do not have directly measured products, indirect and rough techniques of estimation have to be used which yield measures that are conceptually obscure. In general, the methods used to estimate output in these areas tend to understate gains in production and output per man-hour.

In relating output per man-hour trends to other economic variables, care should be taken to insure that comparable measures are used. For example, in making estimates of gross national product based on projections of the labor force, the relevant output per man-hour estimates used to convert labor force projections to gross national product estimates would be those based on the Census labor force data. On the other hand, if the analysis involves a comparison of the trend in output per man-hour and gross average hourly earnings, as measured by the Bureau of Labor Statistics (earnings per hour paid concept) then the output per man-hour measure based primarily on BLS data should be used in the comparison. In such a comparison, it should be noted that the BLS gross average hourly earnings series do not measure total employment costs per hour, since contributions of employers to social security and private health, insurance, pension funds, etc., are not included.

In general, in analyses relating economic growth to technological change as reflected in changes in output per man-hour, the more relevant measure would be that based on the approximation of man-hours worked (labor force data). In comparisons involving labor cost, the output per man-hour measure based on the approximation of hours paid may be more relevant. In the latter case, however, there may be specific instances where estimates of hourly earnings or employment costs per hour have been prepared (by private or government sources) based on the hours worked concept. In such instances, it may be more appropriate to use the output per man-hour measure based on the Census data. For all these comparisons, however, it must be borne in mind that the difference between the two measures of output per man-hour results, in part, from statistical as well as conceptual differences.

The choice of the weight base year may have an effect on the trend, and this should also be taken into account. In general, the selection of a weight base year or average of years at the beginning of the period being measured will tend to show a higher rate of increase than one based on the latter part of the period.

Another caution to be observed in interpreting the measures is that the estimates for the total private economy and major subgroups are not indicative of the trend for individual component sectors, industries, or corporate entities. The previous work of the Bureau of Labor Statistics in manufacturing and other areas indicates quite clearly that there is, in fact, substantial variation from industry to industry and among groups of industries.

Year-to-year changes in output per man-hour or in the relationship of output per man-hour to other economic variables are not uniform, and are therefore not indicative of trends in the basic forces making for productivity growth. It also follows from the lack of uniformity in year-to-year changes in output per man-hour that the choice of the particular time period covered by the measures may affect the resulting estimate of average change.

Appendix E. Technical Note on Long-Term Trends in Output per Man-Hour

As indicated earlier in this report, there are various ways in which long-term trends in output per man-hour for the private economy can be measured. The results obtained depend in part upon the particular form of statistical description selected to summarize the movements. Among these, two types of measures--linear and curvilinear--were examined, and at the same time two forms of curvilinear measures--a parabola and a hyperbola were included.

The procedure used for deriving the trend measure, whether linear or curvilinear, was to apply the least squares technique to the logarithms of the index numbers. This involved solving for the particular line or curve which would minimize the sum of the squares of the deviations of the actual indexes from the proposed line or curve.

The equations are of the following form:

Straight Line	$\text{Log } Y = a + bX$
Parabola	$\text{Log } Y = a + bX + cX^2$
Hyperbola	$\text{Log } Y = a\sqrt{1+\left(\frac{X+c}{b}\right)^2}$ 1/

Table E-1 presents the equations for the linear, parabolic, and hyperbolic trend measures derived from the indexes based on both BLS and Census man-hours. Included also are the equations for the linear and parabolic trends in output per man-hour after adjustments have been made for the effects of shifts and for changes in the degree of capacity utilization. In this table "Y" represents the derived index of output per man-hour; "X" represents the number of years from 1933 (about the middle) of the long-term period, 1909-58); and "Z" represents the employment-labor force percentages (capacity utilization).

Since the line, parabola and hyperbola are included as trend measures, there is a question as to which furnished the best fit to the data. The sum of the squared deviations of the logarithms of the actual indexes from the logarithms of the derived measure is smallest for the hyperbola. The sum for each of the curves is smaller than the sum for the linear trend.

The usual tests of the significance of the differences between the equations fitted to the same data, typically involve in one way or another comparison of the standard errors of the estimates derived from the sums of the squares of the deviations for the various equations. These tests are based on the assumption that the deviations observed are randomly distributed and serially independent.

1/ The equation is derived from the more common form $\left(\frac{Y}{a}\right)^2 - \left(\frac{X+c}{b}\right)^2 = 1$

In many time series, these conditions are not satisfied. The indexes for the current year are influenced to a considerable extent by the level of the indexes for the previous year. Therefore, the consecutive indexes in a time series are not independent but tend to be correlated, a factor known as serial correlation. For example, inspection of the actual and derived series on output per man-hour (charts E-1-E-4) show that for many of the subperiods, the successive deviations between the actual and derived indexes are of the same sign. This illustrates the existence of serial correlation in the output per man-hour series.

Where the deviations are not randomly distributed or independent, strict tests of significance can be applied only when a specific model of the probability scheme under which the differences observed are generated is assumed to be known. There is no generally accepted model which can be applied to most serially correlated time series data. 2/

2/ For a more detailed analysis of the limitations in applying standard statistical tests to time series data, see M. G. Kendall, The Advanced Theory of Statistics, Vol. II, Chapters 29 and 30, pp. 363-439, Haffner Publishing Co., New York 1951, and W. A. Wallis and H. C. Roberts "Statistics, A New Approach," pp. 559-569, The Free Press, Glencoe, Illinois, 1956.

Table E-1. Linear and curvilinear equations of trends in output per man-hour, 1909-58

(1933 is point of origin for years)

Item	Output per man-hour based on --	
	BLS man-hours	Census man-hours
	Linear	
Total change in output per man-hour ...	Log Y = 1.854616 + .009915X or $Y = (71.6)(1.023)^X$	Log Y = 1.858257 + .010105X or $Y = (72.2)(1.024)^X$
Agricultural-nonagricultural proportions constant with:		
1909 output proportions	Log Y = 1.880058 + .008823X or $Y = (75.9)(1.021)^X$	Log Y = 1.892828 + .008950X or $Y = (78.1)(1.021)^X$
1958 output proportions	Log Y = 1.876293 + .008817X or $Y = (75.2)(1.021)^X$	Log Y = 1.881154 + .008961X or $Y = (76.1)(1.021)^X$
1909 man-hour proportions	Log Y = 1.876134 + .008837X or $Y = (75.2)(1.021)^X$	Log Y = 1.880859 + .008977X or $Y = (76.0)(1.021)^X$
1958 man-hour proportions	Log Y = 1.874112 + .008810X or $Y = (74.8)(1.020)^X$	Log Y = 1.879209 + .008980X or $Y = (75.7)(1.021)^X$
Adjusted for change in capacity utilization	Log Y = 1.539121 + .009879X + .003415Z or $Y = (34.6)(1.023)^X(1.008)^Z$	Log Y = 1.529101 + .010068X + .003563Z or $Y = (33.8)(1.023)^X(1.008)^Z$

Table E-1. Linear and curvilinear equations of trends in output per man-hour, 1909-58--Continued

(1933 is point of origin for years)

	Output per man-hour based on --	
	BLS man-hours	Census man-hours
Curvilinear - Parabola		
Total change in output per man-hour..	$\log Y = 1.829345 + .009794X + .000121X^2$ or $Y = (67.5)(1.023)^X(1.0003)^{X^2}$	$\log Y = 1.830326 + .009971X + .000134X^2$ or $Y = (67.7)(1.023)^X(1.0003)^{X^2}$
Agricultural-nonagricultural proportions constant with:		
1909 output proportions	$\log Y = 1.852426 + .008690X + .000133X^2$ or $Y = (71.2)(1.020)^X(1.0003)^{X^2}$	$\log Y = 1.864464 + .008814X + .000136X^2$ or $Y = (73.2)(1.021)^X(1.0003)^{X^2}$
1958 output proportions	$\log Y = 1.856383 + .008721X + .000096X^2$ or $Y = (71.8)(1.020)^X(1.0002)^{X^2}$	$\log Y = 1.858728 + .008854X + .000108X^2$ or $Y = (72.2)(1.021)^X(1.0002)^{X^2}$
1909 man-hour proportions	$\log Y = 1.856695 + .008743X + .000093X^2$ or $Y = (71.9)(1.020)^X(1.0002)^{X^2}$	$\log Y = 1.859031 + .008872X + .000105X^2$ or $Y = (72.3)(1.021)^X(1.0002)^{X^2}$
1958 man-hour proportions	$\log Y = 1.858992 + .008737X + .000073X^2$ or $Y = (72.3)(1.020)^X(1.0002)^{X^2}$	$\log Y = 1.861437 + .008895X + .000085X^2$ or $Y = (72.7)(1.021)^X(1.0002)^{X^2}$
Adjusted for change in capacity utilization	$\log Y = 1.626669 + .009802X + .000089X^2 + .002268Z$ or $Y = (42.3)(1.023)^X(1.0002)^{X^2}(1.005)^Z$	$\log Y = 1.629596 + .009980X + .000102X^2 + .002246Z$ or $Y = (42.6)(1.023)^X(1.0002)^{X^2}(1.005)^Z$
Curvilinear - Hyperbola		
Total change in output per man-hour..	$\log Y = 1.6539\sqrt{1 + \left(\frac{X + 33.22}{70.35}\right)^2}$ or $Y = (45.1)\sqrt{1 + \left(\frac{X + 33.22}{70.35}\right)^2}$	$\log Y = 1.6631\sqrt{1 + \left(\frac{X + 31.12}{67.75}\right)^2}$ or $Y = (46.0)\sqrt{1 + \left(\frac{X + 31.12}{67.75}\right)^2}$

Chart E-1. Indexes and Linear and Parabolic Trends of Real Product Per Man-Hour in the Total Private Economy, 1909-58

Post-World War II Period Based Primarily on Census Man-Hours

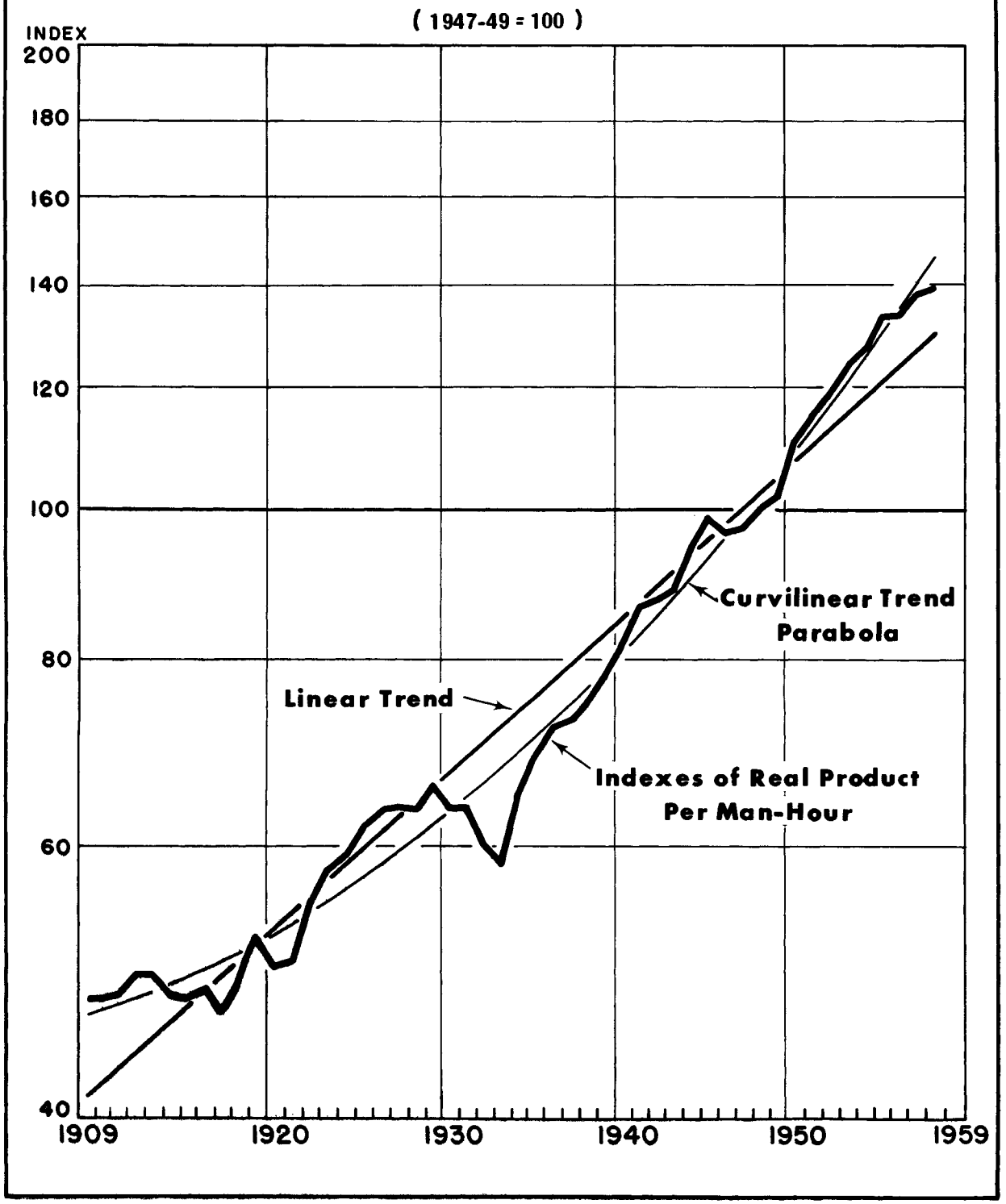


Chart E-2. Indexes and Linear and Hyperbolic Trends of Real Product Per Man-Hour in the Total Private Economy, 1909-58

Post-World War II Period Based Primarily on Census Man-Hours

(1947-49 = 100)

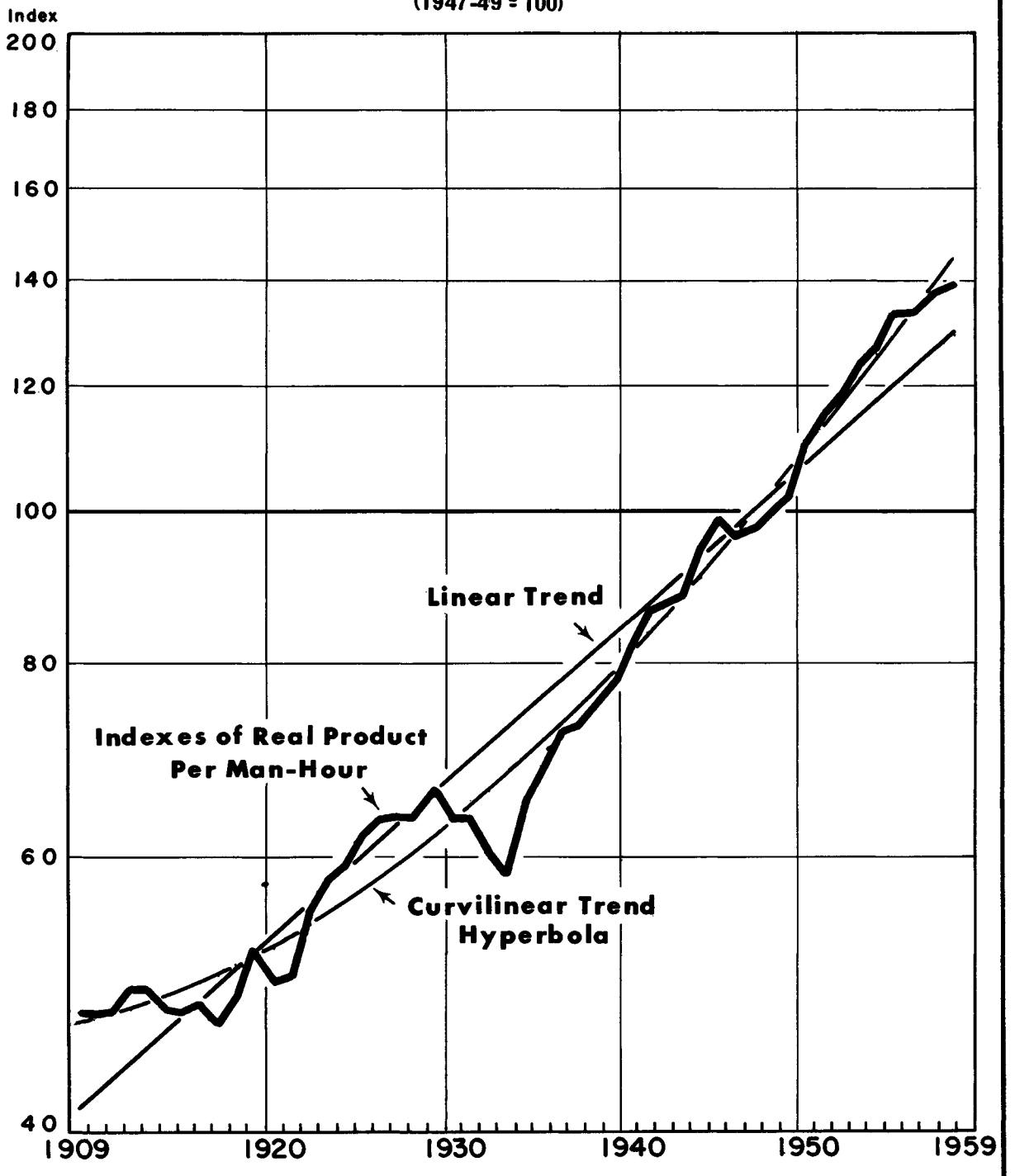


Chart E-3. Indexes and Linear and Hyperbolic Trends of Real Product Per Man-Hour in the Total Private Economy, 1909-58

Post-World War II Period Based Primarily on BLS Man-Hours

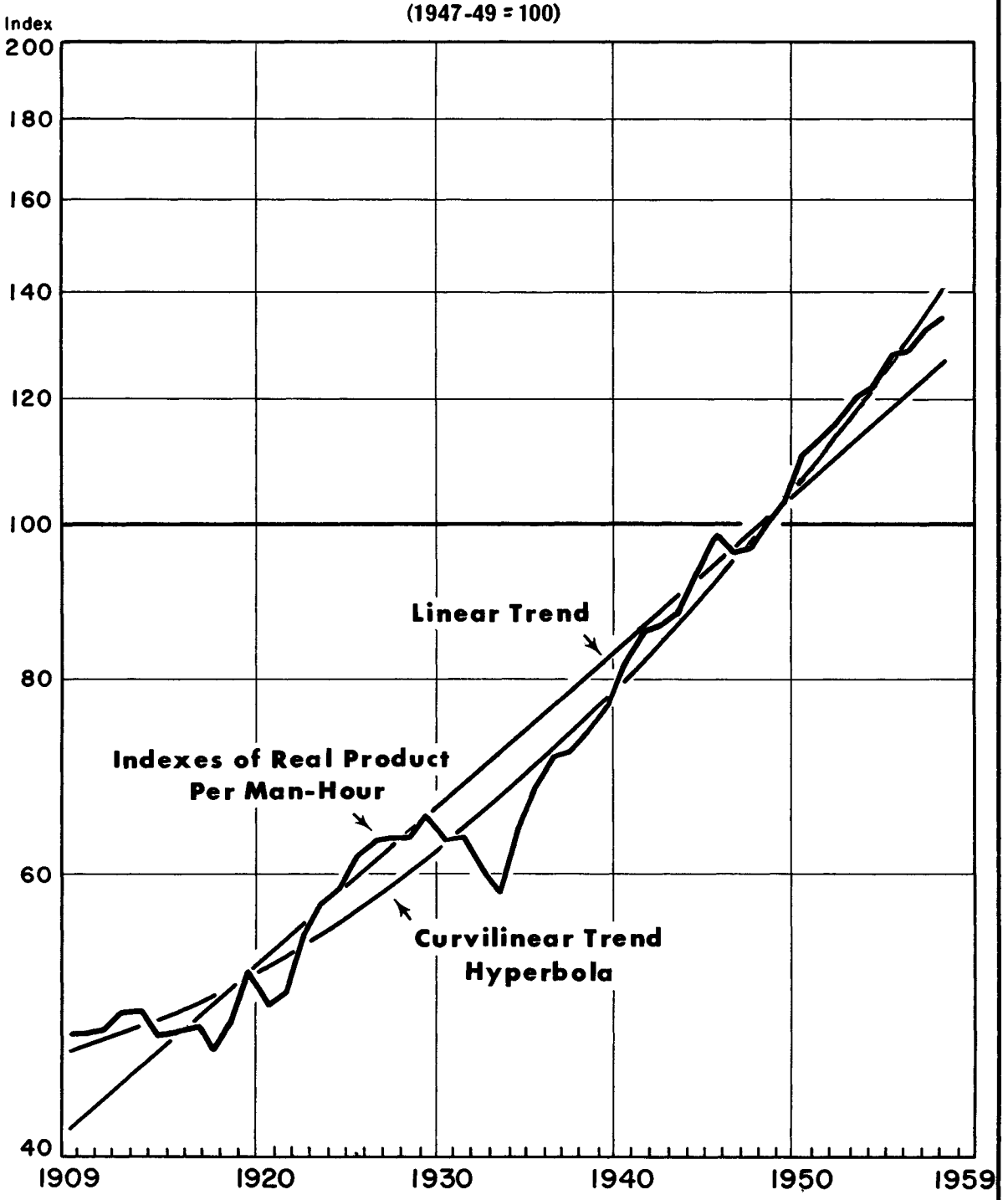
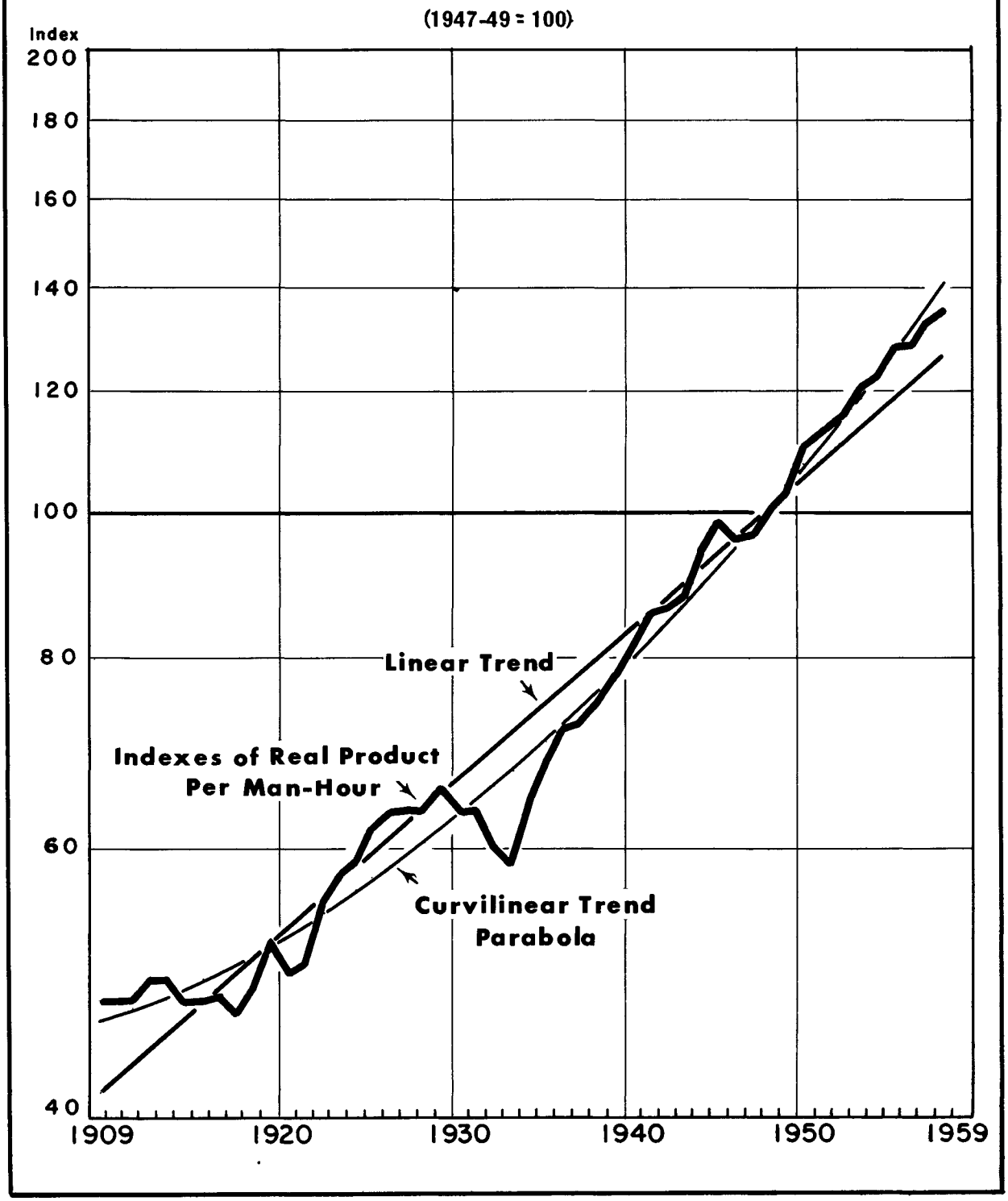


Chart E-4. Indexes and Linear and Parabolic Trends of Real Product Per Man-Hour in the Total Private Economy, 1909-58

Post-World War II Period Based Primarily on BLS Man-Hours



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* U.S. GOVERNMENT PRINTING OFFICE : 1960 O—538511