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Productivity and its Measurement

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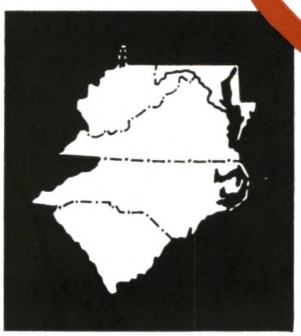


JUNE 1971

PRODUCTIVITY AND ITS MEASUREMENT

The subject of productivity occupies a prominent position in discussions of national economic policy. Its official recognition was underscored by President Nixon's appointment of the National Commission on Productivity last June. Long of interest to economists, plant managers, industrial engineers, and labor union leaders, productivity in the past two decades increasingly has become the concern of economic policymakers. In econometric models too, productivity shares top billing with other economic variables such as the money supply, interest rates, the price level, profits, and the unemployment rate.

Recent interest in productivity as an economic variable stems from two developments. First, empirical studies have shown that productivity growth has contributed more to long run increases in national product than has the growth of both labor and capital inputs as those inputs are conventionally measured (i.e., exclusive of quality improvements or technical change embodied in them). Second, the post-1965 experience of rising wages and prices has focused attention on the link between productivity and inflation. If wage rates grow faster than productivity, inflation may result. The productivity-inflation nexus has influenced anti-inflation policy. For example, the Kennedy-Johnson wage-price guideposts embodied the principle that wages should grow no faster than productivity. Policymakers also have learned that a higher rate of productivity growth will provide them with a more attractive menu of choices between inflation and unemployment.

More will be heard about productivity; the President has directed the National Commission on Productivity to study and report on ways ". . . to achieve a balance between costs and productivity that will lead to more stable prices." A clear understanding of productivity may aid the public in evaluating future policy discussions. This article discusses the concept and behavior of productivity, as well as the techniques and problems involved in its measurement. The article is divided into four sections, the first of which considers several concepts and measures of productivity. Subsequent sections discuss the long-term productivity trends in the U. S., the short-term or cyclical behavior of productivity, and some major unresolved problems in the measurement of productivity.

MEASURES OF PRODUCTIVITY

Productivity may be expressed in terms of output-input ratios. A productivity ratio is a measure of input efficiency, i.e., it indicates how many units of output can be obtained from a unit of input. Productivity measures exist in a variety of forms, e.g., corn production per acre of land, industrial output per dollar of invested capital, calorie output per unit of food, miles per gallon of gasoline, and kilowatt hours generated per ton of coal. The two most widely used measures of productivity in economics, however, are *labor productivity,* or output per unit of labor input, and *total factor productivity,* or output per unit of labor and capital combined. Labor productivity and total factor productivity indexes can be calculated for individual firms, industries, groups of industries, and for the national economy. This article is concerned primarily with national productivity indexes. Measures of national productivity all use some variant of real national output as the numerator of the productivity ratio.

Labor Productivity Labor productivity may be measured alternatively as (1) output per man employed (Q/M), (2) output per labor-hour (Q/L), or (3) output per weighted labor-hour ($Q/\Sigma w_i L_i$), where labor-hours are weighted by the hourly earnings of different industries in which they are employed. Of the three measures, the second is used most frequently. The most familiar measure of labor productivity in the United States is the index of output per man-hour computed by the Bureau of Labor Statistics. The BLS index is the productivity measure cited in most official economic policy statements as well as in the annual *Economic Report of the President* and in recent "Inflation Alerts" prepared by the President's Council of Economic Advisors. The BLS productivity measure is calculated by dividing constant dollar Gross National Product originating in the private sector by the corresponding labor-hours employed in the private sector. Estimates of man-hours employed are obtained from

monthly surveys of households and from the payroll records of a sample of business firms. The BLS index covers only the private sector of the economy. The government sector is excluded because of the difficulty of measuring government output. Unlike the easily identifiable product of the private sector which is sold on the market at specific prices to individual buyers, the product of the government sector chiefly takes the form of nonmarketed services provided to meet collective needs.

A man-hour productivity measure (Q/L) such as the BLS's, has several advantages over a man employed measure (Q/M). Its man-hour dimension facilitates its comparison with hourly wage rates. Moreover, for comparison of productivity changes over time or of productivity differentials between countries, the man-hour measure is more accurate than the man employed measure because it takes into account changes in the length of the work week and international differences in the number of hours worked per laborer.

In the BLS productivity index, the aggregate labor input is simply the unweighted sum of man-hours worked in all industries. In such an unweighted index an hour of work by a brain surgeon is treated as being equivalent to a ditch-digger's hour of work. Some leading private researchers, such as Professor John W. Kendrick of George Washington University, have attempted to adjust the man-hour productivity measure for interindustry differentials in labor quality. These researchers have prepared weighted labor-hour productivity indexes ($Q/\Sigma w_i L_i$) in which the labor input is calculated as the sum of the labor-hours in each industry weighted by the wage rate in those industries. Relative wage rates are presumed to measure the relative quality of labor inputs. That is, relative wage rates here represent the many factors, e.g., differences in education, skill, experience, etc., accounting for interindustry differentials in labor quality. A highly priced man-hour is counted proportionately more than an hour of lower wage labor. For example, in the weighted index, a labor-hour in an industry paying a $6.00 hourly wage is treated as being equivalent to three labor-hours in an industry where the wage rate is $2.00.

The BLS labor productivity index is a useful but very crude indicator of the economy's changing productive efficiency. Its virtues include ease of calculation and its relatively modest information requirement. The output per man-hour index, however, can be misleading. It is a partial productivity index which compares output with only one input without giving explicit recognition to the contribution of other inputs. The index overstates the growth of the economy's productive efficiency because the productivity ratio (Q/L) includes only man-hours in the denominator. Moreover, the use of output per man-hour as a measure of the rise in the economy's productive efficiency may suggest to the unwary that labor alone has been responsible for the advance in efficiency. Actually, a number of forces have operated to raise man-hour productivity. These include the substitution of capital for labor, advances in technology, improvements in managerial and organizational technique, increasing specialization allowed by widening markets, rising levels of skill, training and health of the labor force, and changes in both the age and sex composition and the industrial distribution of the labor force. But the individual contributions of these factors are concealed in the output per man-hour index.

Total Factor Productivity Recently, researchers have developed another productivity index, the total factor productivity (TFP) index, to aid in the specification of some of the efficiency-augmenting factors concealed by the labor productivity index. Unlike the labor productivity measure, the TFP measure compares output not only with man-hour inputs, but with capital equipment inputs and with a variable representing a host of other forces affecting output as well. Because the TFP measure has proved so useful in efforts to isolate the sources of the long-term advance of the U. S. labor productivity index, it warrants detailed examination.

In constructing the TFP index, the statistician begins by postulating a relation between output and inputs for any year (t) defined by the production equation,

$$(1) \quad Q_t = T\,(w_o L_t + i_o K_t).$$

Here, Q is output, L and K are the labor and tangible capital (including plant, equipment, machinery, inventory and land) inputs, w_o is the real wage rate of labor in the base period, i_o is the real interest return to capital in the base period, and T represents all the other forces such as technical progress which contribute to output by affecting the productive efficiency of labor and capital.

In using the production equation the statistician assumes (1) that the base period real rates of remuneration (w_o and i_o) were equal to the base period productivities of a man-hour of labor and a machine hour of capital, i.e., an hour of labor and an hour of capital were paid what they produced; (2) that the total payments (hourly rates of re-

muneration multiplied by the number of factor hours) made to labor and capital in the base period just exhausted the total output produced by those inputs ($Q_o = w_oL_o + i_oK_o$), and (3) that, as a corollary, the term T has a value of unity in the base period.

Now the statistician wishes to measure the effect which growing *efficiency*—not the growing labor force or capital stock—has on output. How does he do it? The production equation $Q_t = T(w_oL_t + i_oK_t)$ shows that the labor and capital inputs in any given year (t) are weighted by their base period real prices. This weighted sum of inputs ($w_oL_t + i_oK_t$) provides the statistician with a measure of what the labor and capital inputs in the given year would have produced if their productive efficiency (and hence rates of return w_o and i_o) had remained the same in the given year as in the base period ($t = o$). Obviously, if the efficiency of labor and/or capital has increased since the base period, the term ($w_oL_t + i_oK_t$) will be less than Q_t, and T must be greater than 1 if both sides of the production equation are to be equal. This rise in the value of T over its base period value of 1 represents the gain in the efficiency of labor and capital inputs.

The production equation can be rewritten as

$$(2) \quad T = \frac{Q_t}{w_oL_t + i_oK_t},$$

where T is the measure of TFP. It is a measure of all other forces besides capital accumulation and labor-force growth that contribute to growth of output. As mentioned earlier, T is given a value of 1 in the base period ($T_o = 1$) and will rise over time as the productivity of labor and capital increases. In practice the statisticians express the TFP measure in index number form (relatives or ratios of period t values to base period values) with the inputs weighted in proportion to their *shares* in output in the base period. The formula is

$$(3) \quad \frac{T}{T_o} = \frac{Q_t/Q_o}{a(L_t/L_o) + b(K_t/K_o)},$$

where a = labor's base period share and b = capital's base period share. It can be shown that equation (3), in which factor prices have been replaced with factor shares, is equivalent to equation (2), since the base period share of either factor is defined as the total payment made to the factor expressed as a fraction or share of the base period output.[1]

The appearance of capital in the TFP index presents the statistician with two problems not encountered in the measurement of labor productivity. First, available data are estimates of the *stock* of tangible capital equipment, whereas it is a measure of the *flow* of capital services that is sought. The statistician overcomes this difficulty by assuming that the services flowing from the capital stock are proportional to the size of the stock and therefore the latter is a good proxy for the former. Second, the statistician must be able to convert the capital stock into input units comparable to man-hour units. In practice, this is accomplished by assuming, for example, that each $100 worth of tangible capital yielding an annual interest income of $5, is equivalent to five labor-hours receiving an hourly wage rate of $1 each.

THE LONG TERM (TREND) BEHAVIOR OF PRODUCTIVITY

Chart 1 indicates John Kendrick's estimates of the persistent long-term advance of measured productivity in the U. S. The chart also compares the increase of man-hour output with the rise in hourly wages since 1889. The significance of the long-term rise in labor productivity for the standard of living of U. S. workers is indicated by the close coincidence of the wage and productivity series.

Kendrick estimates that the average annual growth rate of output per man-hour over the period 1889-1969 was 2.4%. During the past 15 years much research has been devoted to specifying the basic forces underlying this sustained secular rise in the labor productivity index. This research has identified the sources of man-hour productivity growth as (1) improvements in the quality of the labor force (often called "investment in human capital"), (2) a rising ratio of capital to labor, and (3) growing efficiency (as measured by the rise in the total factor productivity index) in the use of the nation's labor and capital resources. Each of these sources is discussed below.

Sources of Productivity Growth Improvements in the average quality of labor have been estimated by various reseachers to comprise between a sixth and a third of the 2.4% labor productivity growth rate. Accounting for advances in the quality of the labor force are such factors as more education, less child labor, and a higher average level of skill as a growing proportion of the work force is engaged in skilled occupations.

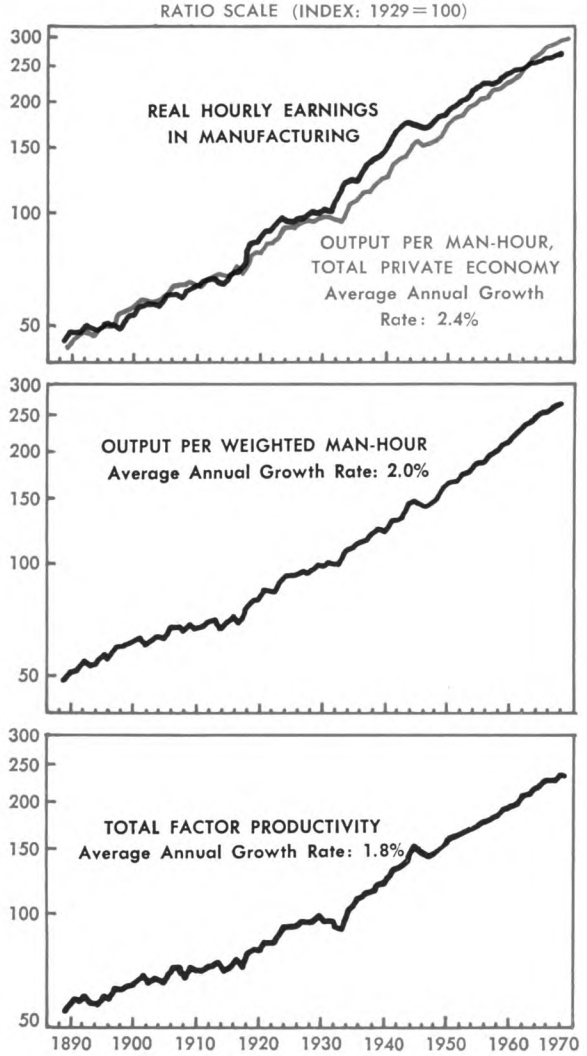
Several techniques have been employed by researchers attempting to isolate the quality factor. Data on age, sex, and length of formal education —labor force characteristics thought to be closely

[1] That is, $a = w_oL_o/Q_o$ and $b = i_oK_o/Q_o$. Substitution of these expressions for a and b into equation 3 will yield equation 2.

Chart 1

PRODUCTIVITY INDEXES, 1889-1969

RATIO SCALE (INDEX: 1929=100)



Sources: Solomon Fabricant, **Basic Facts on Productivity Change**, New York, National Bureau of Economic Research, 1958; John W. Kendrick, **Productivity Trends in the United States**, Princeton: Princeton University Press, 1961. John W. Kendrick, **Postwar Productivity Trends in the United States 1948-1969**, New York: National Bureau of Economic Research, M.S.; U. S. Council of Economic Advisors, **Economic Report of the President**, 1971.

correlated with labor quality—have been used to derive separate indexes of the productivity contribution of each labor quality. This procedure was employed by E. F. Denison, who estimated that improved education, together with several other components of quality change in the labor force, accounted for between a third and a fourth of the growth rate of output per man-hour.[2] Another method is to adjust the estimate of aggregate man-hours' contribution to output growth for changes in specified elements of labor quality. A third technique uses shifts in the industrial composition of the labor force as a proxy for quality change. This latter technique was used by John Kendrick and provided the rationale for his derivation of the weighted man-hour productivity index that appears in Chart 1. Kendrick used information on just one characteristic associated with labor quality, namely the industry to which the worker is attached. He assumed that interindustry wage differentials reflected differences in labor quality. He attempted to isolate the labor quality effect by (1) calculating a productivity index in which man-hours in different industries were weighted by wage rates in those industries and (2) comparing this weighted index with the unweighted labor productivity index. The difference between the two indexes supposedly captures the quality effect. The shift in the industrial distribution of labor from low to high wage industries provides Kendrick with his estimate of the increase in the average quality of labor, about 0.4% a year. This figure (0.4%) is the difference between the trend growth rates of the unweighted and weighted labor productivity indexes shown in Chart 1. The contribution which improved labor quality makes to the growth rate of productivity is estimated by multiplying the rate of improvement of labor quality by the relative importance of labor as a factor of production as measured by its share of total output:

(Percent improvement in labor quality) X (labor's share of output) = (0.4) X (.75) = 0.3 percent per annum.

Another source of productivity advance is the secular rise in the amount of capital equipment each unit of labor has to work with. Since 1889 the stock of tangible capital has grown sixfold while labor-hours have doubled resulting in a tripling of the ratio of capital per man-hour. This threefold increase in the ratio of capital to man-hours, however, accounted for only 0.4 percentage points of the productivity growth rate. This figure is obtained by multiplying the growth rate of the capital-labor ratio by capital's relative importance as an input as measured by its share of output:

(percent increase in capital per man-hour) X (capital's share of output) = (1.6) X (.25) = 0.4.

The capital-labor ratio's contribution to productivity growth seems startlingly small in light of the key role traditionally assigned to capital formation in economists' analysis of economic development. Since the time of Karl Marx, most economists have

[2] E. F. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us*, (New York: Committee for Economic Development, 1962), pp. 148-50.

considered increased tangible capital per man-hour to be the strategic cause of increased output per man-hour. But the above estimates do not support this conception. Capital's actual, measured contribution to productivity growth seems far smaller than economists once presumed it to be.

By far the greatest contributor to the advance in output per man-hour has been the growing efficiency in the use of labor and capital as measured by the total factor productivity index. Approximately two-thirds of the growth of labor productivity is accounted for by this source. As was mentioned earlier, "efficiency," or total factor productivity, is a portmanteau concept. It includes a host of forces affecting man-hour productivity. In the past decade, much research effort has been devoted to breaking down the measure of factor productivity in order to reveal its constituent elements. Several separate components have been identified. These include (1) "technological change," i.e., the generation and advance of new knowledge pertaining to technology and to managerial and organizational techniques; (2) economies of scale or increasing returns due to the growth of markets which allowed greater specialization and division of labor; (3) restrictions such as monopoly power, tariffs, quotas, taxes, legal price ceilings or price floors and racial discrimination that obstruct the optimum use of resources; (4) reduction in the average hours of work per week; and (5) shifts in the composition of national output away from low productivity to high productivity industries, for example, the decline in domestic service relative to manufacturing.

In summary, the relationship described in the preceding paragraphs between the growth rate of labor productivity and its components may be written:

$$q_l = a\lambda + bk_l + t, \qquad \text{where}$$

q_l, λ, k_l, t are respectively the percentage rates of increase of man-hour productivity, labor force quality, the capital-labor ratio, and that part of total factor productivity not attributable to improvement in labor quality, and a and b are the respective output shares of labor and capital. Estimates of the relative contribution of each component to productivity growth vary among studies. Kendrick's study, one of the most complete, suggests that improved labor quality, a rising ratio of capital to labor, and growing TFP accounted for roughly one-sixth, one-sixth, and two-thirds, respectively of the 2.4% trend growth rate of output per man-hour.

Table I

GROWTH RATES IN PRODUCTIVITY RATIOS
1889-1969
(Average annual percentage rates of change)

Period	Output Per Man-Hour	Output Per Weighted Man-Hour	Total Factor Productivity
1889-1968	2.4	2.0	1.8
1889-1919	2.0	1.6	1.3
1919-1948	2.2	1.9	1.8
1948-1969	3.1	2.8	2.3

Source: J. Kendrick, **Productivity Trends in the United States**, Princeton: Princeton University Press, 1961, and **Postwar Productivity Trends in the United States, 1948-1969.** New York: National Bureau of Economic Research, Manuscript.

Variation in Long Term Trends Although the secular trend in productivity has been continually upward, the rate of advance has not been uniform. Table I shows the variations in trend rates for various subperiods of the interval 1889-1969. As indicated in the table, productivity's growth was slowest in the earliest period shown and highest in the post World War II period. Some observers have interpreted these figures as evidence of a steadily accelerating productivity trend. Many experts however, are skeptical of this hypothesis. They think that there have been breaks or discontinuities in the trend. They acknowledge that the postwar trend is higher than the prewar one, but they doubt that the former trend is accelerating. In fact, the BLS has forecast a 3.0% growth rate for productivity over the decade of the 1970's, 0.1 percentage points below its postwar trend. The majority of productivity experts would probably agree that the normal trend growth established after World War II is slightly higher than 3.0%.

THE CYCLICAL BEHAVIOR OF PRODUCTIVITY

Output per man-hour exhibits a definite short-run, cyclical pattern apart from its long run behavior. This cyclical pattern has been observed by experts such as Edwin Kuh of Harvard and Solomon Fabricant of the National Bureau of Economic Research. Fabricant's estimates, shown in Table II, indicate that the rate of increase in labor productivity in the manufacturing sector tends to be low in the early phase of contractions, much higher toward the end of contractions and the beginning of expansions, and lower in the later stage of expansions.

Chart 2 contains a hypothetical example that il-

Table II

AVERAGE RATES OF CHANGE IN LABOR PRODUCTIVITY IN MANUFACTURING INDUSTRIES DURING TEN BUSINESS CYCLES 1919-1961

CYCLE PHASE	Average Annual % Rate of Change
First Half of Contraction	0.8
Second Half of Contraction	2.8
First Half of Expansion	5.3
Second Half of Expansion	3.0

Source: Solomon Fabricant, **A Primer on Productivity** (New York: Random House, 1969) p. 91.

lustrates the relation between short-term movements in economic activity and in labor productivity that has been observed in U. S. business fluctuations. The top panel of the chart shows the path of real national income over a "typical" business cycle. The trough-to-trough duration of the cycle is divided into four stages—the recovery, expansion, downturn, and contraction stages. The second panel of Chart 2 depicts the cyclical behavior of productivity's growth rate. The chart illustrates that, while productivity tends to advance over the whole cycle, its rate of advance varies sharply from phase to phase. Productivity growth accelerates in the contraction and recovery stages but decelerates in the later expansion and downturn phases.

The chief forces affecting the cyclical movements of productivity are (1) cyclical changes in the quality of the labor unit and of capital equipment and (2) capacity utilization rates of both capital equipment and "overhead" labor. Overhead labor refers to employees retained or "hoarded" by employers in the face of cutbacks in output either because they possess specialized skills, or because employers have made contractual commitments (such as a guaranteed annual wage) to them, or because employers wish to avoid costs (e.g., severance pay) of laying off labor as well as the costs of rehiring and retraining workers when business conditions improve.

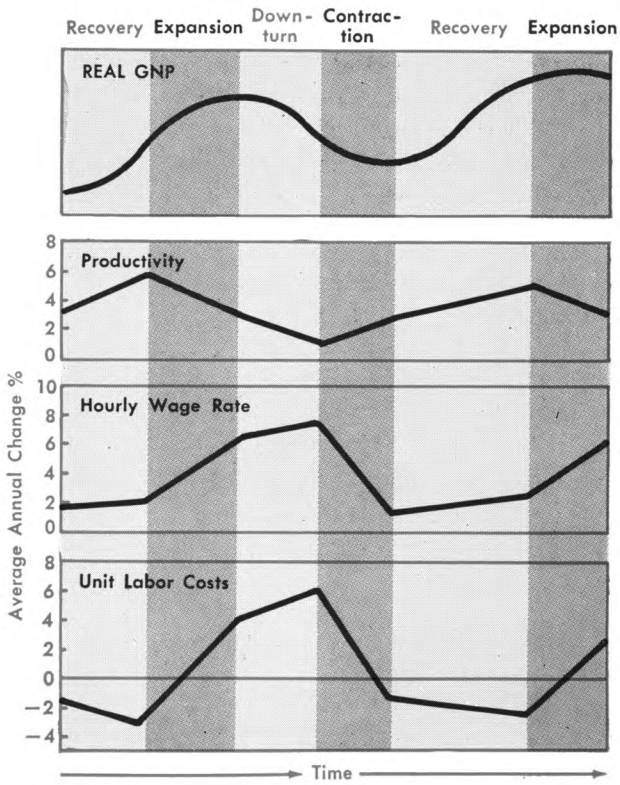
In the recovery stage these factors combine to stimulate productivity. As output expands, producers utilize formerly idle plant and equipment, and capacity utilization rates rise toward their most efficient levels. Improvement in the quality of capital contributes to productivity too. Some of the capital put into use is new and technologically superior equipment ordered during the preceding boom which, because of production backlogs in the capital goods producing industries, may not have been delivered and installed until the contraction stage. The spreading of overhead labor over a larger volume of production also increases efficiency. Moreover, the existence of a still substantial pool of unemployed labor enables employers to select highly qualified workers as hiring steps up.

In the expansion stage of the cycle productivity rises less rapidly than in the preceding recovery phase. As economic activity nears its peak, operating rates of plant and equipment reach and then surpass their most efficient levels. Further increases in capacity utilization contribute little to labor productivity. Hours of labor begin to exceed the normal length of the workday. These overtime hours fatigue workers and are generally less productive than normal hours. With unemployment at low levels, management must recruit additional labor from the ranks of the unskilled or unexperienced. In addition, labor discipline deteriorates when the labor market is tight. All of these factors combine to decelerate the rate of productivity increase.

The deceleration becomes even more pronounced in the downturn stages of the cycle. As output declines, the rate of capital utilization falls below its

Chart 2

BEHAVIOR OF GROWTH RATES OF PRODUCTIVITY, WAGE RATES, AND UNIT LABOR COST OVER HYPOTHETICAL BUSINESS CYCLE



most efficient level. But the use of labor does not fall as fast as output. Much of the salaried and overhead labor is retained. Employers attempt to maintain their work-forces for a while by cutting overtime hours rather than laying off men. Capital-labor and output-labor ratios fall below optimal levels.

Productivity rebounds sharply in the contraction stage of the cycle. Although there is no increase in the degree of capacity utilization, there is a strengthening of other forces underlying productivity advance. By this time, firms have eliminated much of their redundant labor. The inexperienced and least productive workers have been laid-off, thereby raising the average quality of the employed. Available work is shifted to new and technologically advanced equipment ordered in the boom but only recently delivered. These forces account for the surge in productivity.

Productivity, Wage Rates, and Unit Labor Costs

What do productivity movements have to do with inflation, i.e., how is output per man-hour linked to the price level? Productivity affects the price level via its influence on labor costs per unit of output (called unit labor costs, ULC). Unit labor costs are equal to hourly wage rates (including fringe benefits) divided by productivity

$$(\mathrm{ULC} = \frac{\mathrm{w}}{\mathrm{Q/L}}).$$

Whether ULC rises or falls depends upon which one—wages or productivity—is rising the faster. If wage rates rise faster than productivity, ULC will rise. As ULC comprises the largest component of production cost per unit of output of most goods and services, a rise in ULC is likely to result in a rise in prices.

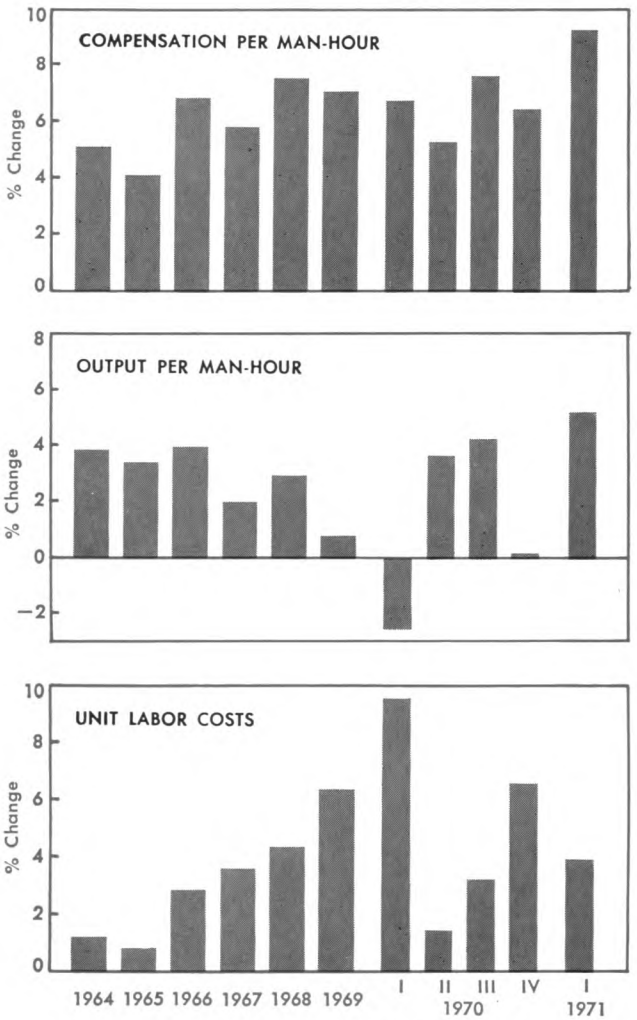
The cyclical productivity-wage-ULC relationship is illustrated in the lower three panels of Chart 2. As indicated in the bottom panel, the percentage change in ULC is equal to the difference between the percentage changes in wage rates and the percentage change in productivity. The third panel of the chart illustrates the tendency for wage rates to rise most rapidly during the late expansion and early downturn phases when the labor market is tight and to rise less rapidly in the contraction and early recovery stages when the labor market is slack.

Observe the behavior of ULC in the bottom panel of the chart. During the recovery period of the cycle the rapidly rising growth of productivity combined with the sluggish growth of wages operates to reduce ULC. In the boom or expansion phase, ULC rise as wage increases accelerate and productivity growth slows. During the early downturn ULC may rise even faster than in the boom as productivity growth continues to plummet while wage increases remain high. Finally, in the contraction stage, rebounding productivity growth combines with the slowing rate of increase of wages to bring a decline in ULC.

The foregoing illustration seems to describe fairly well what has been happening since 1965. Chart 3 shows that from 1966 through the first quarter of 1970, compensation per man-hour increased rapidly, productivity advance slowed and ULC rose at an accelerated pace. In the second and third quarters of 1970, however, the rate of rise of man-hour com-

Chart 3

CHANGES IN COMPENSATION, PRODUCTIVITY, AND LABOR COSTS IN THE PRIVATE SECTOR, 1964-1971



Source: U. S. Department of Labor, **Monthly Labor Review**, various issues.

pensation leveled off, productivity registered substantial gains, and the rise of ULC slowed. After a temporary lapse in the last quarter of 1970, productivity growth surged vigorously in the first quarter of 1971. Some observers believe that, with the exception of the strike-distorted fourth quarter of 1970, the recent behavior of productivity and ULC fits the pattern of an economy beginning to rebound from a cyclical trough.

If past experience is any indication, productivity can be expected to rise sharply during the first stage of the rebound. That is, during the upswing we can get rapid expansion of output and employment simultaneously with a fall in the inflation rate. Apparently this is the reasoning of those economists who argue that the economy can approach the full employment zone at a rapid clip without fear of reigniting inflation as long as the upswing starts from an initial position of substantial unemployment. For a while, then, progress can be made on both the inflation and unemployment fronts. These same economists are quick to point out, however, that the respite granted by rising productivity will be only temporary. When the economy approaches the zone of full employment, productivity's growth will slow and the expansion will have to be decelerated if inflation is to be avoided.

PROBLEMS OF MEASUREMENT

Even though much work has been done to eliminate bias in productivity indexes, these indexes are still only crude approximations of perfect measures. The statistical information available for calculating productivity indexes is still deficient, and conceptual problems of productivity measurement remain unresolved. This section summarizes some of the remaining shortcomings inherent in present methods of estimating productivity growth.

Deficiencies in the Output Measure Most productivity indexes employ private sector real GNP as the output component. But GNP is an imperfect measure of output. It fails to register adequately improvements in the quality of goods and services and it is largely unaffected by the introduction of new products. This deficiency, which arises from the character of price indexes used as deflators in the estimation of real GNP, is especially serious when the rate of technical change is being measured, because a large part of technical change takes the form of improvements in the quality of products and the introduction of entirely new products. But because these improvements go unmeasured, the growth of real output and productivity is understated.

Another deficiency of the GNP measure is that it excludes such nonmarket output as the services of housewives and the product of do-it-yourself activity.[3] On the other hand, it includes certain expenditures incurred in offsetting the unwanted side effects (e.g., pollution) of economic activity. This latter feature may result in the overstatement of productivity when technical progress expands both potential output *and* the level of environmental pollution. To take an extreme example, suppose that technical progress generated so much additional pollution that it was necessary to employ all the extra production potential in the manufacture of pollution-abatement devices. The extra output of the devices would enlarge both conventionally measured GNP and the productivity ratio, but there would be no *real* improvement in either measure.

Deficiencies exist in the estimate of government output included in the GNP. Because of these deficiencies, input-output data of the government sector are excluded in the calculation of many productivity indexes. Yet knowledge of the productivity of resources in the government sector would be invaluable to researchers attempting to assess the government's contribution to the nation's economic welfare. At present, however, output measures for government services do not exist. Instead, GNP statisticians must use the quantity of inputs as a measure of government output even though the economic and social value of government services may differ from the real costs of inputs used to produce them. For example, the economic and social value of crime prevention may far exceed the cost of staffing and maintaining police departments. Similarly, the economic and social value of our system of laws, regulations, and courts may diverge sharply from the cost of maintaining legislative, regulatory, and judicial bodies. But there is no way of knowing for sure because, at present, there is no satisfactory, reliable measure of the output of government services.

Proper Measurement of Inputs On the input side, the chief conceptual problem is how to link technical progress with the labor and capital inputs via a measure of quality change. Many economists believe that if the labor and capital inputs were properly measured so as to fully take into account all improvements in their quality, there would be little output growth left to be explained by the portmanteau concept of total factor productivity. In other words, adequately measured labor and capital inputs could account for most, or all, output growth.

[3] The exclusion of non-market output may not bias the productivity ratio, however, because labor-hours expended in such activity are also excluded from the input measure.

But there is no unanimity of opinion as to how these quality adjustments should be made. One group of economists argues that most of the quality adjustments should be made to the labor input measure because technical change is transmitted through changes in the skill and educational characteristics of the labor force. Another group of experts thinks adjustments should be incorporated solely in the measure of the capital stock on the grounds that technical change is embodied in capital goods and that shiny new machines are necessary to activate new technology. Existing evidence is not sufficient to determine which, if either, view is correct.

Measurement of Productivity Trends The measment of productivity trends also entails some difficulties. It is quite possible for different researchers to arrive at different estimates of the trend. Because indexes of productivity growth are so widely used, both as guides to noninflationary wage settlements and in projections of future manpower requirements, over- or understatement of the trend can have important consequences. For example, wage-price guideposts based upon an overestimated trend will be inflationary, and manpower requirement forecasts based on the same trend estimate will be too low.

Researchers must exercise judgment in selecting the time interval over which the trend is to be measured. If the period selected is too short, the productivity index will capture mainly cyclical changes in productivity rather than trend changes. On the other hand, if the time interval is too long, significant breaks or changes in the trend may be concealed.

Care should also be taken in the selection of the base and terminal dates. The statistician must consider the phase of the business cycle when selecting the end dates of his trend. For example, if the beginning date corresponds to a depressed level of productivity and the terminal date corresponds to a cyclical peak level, the trend line connecting the two productivity levels will display too high a growth rate. Both end dates should be situated in comparable phases of the cycle when productivity is not at abnormal levels.

SUMMARY

The behavior of the output per man-hour index in the U. S. is of great significance. Its century-long recorded growth corresponds to the remarkable improvement in the standard of living of the average U. S. citizen. Its tendency to rise sharply in the late stages of business contractions and early stages of business expansions is expected to be a strategic factor enabling the economy to rebound strongly from last year's recession without engendering added inflation. The productivity index is indeed a key indicator of major secular and cyclical forces at work in the economy.

However, although it is an important economic indicator, the labor productivity index nevertheless lacks explanatory power. A rising labor productivity index signifies the occurrence but does not explain the causes of economic growth. This shortcoming led to the development of the total factor productivity index, a measure better suited than the man-hour productivity index to isolate the sources of growth. Using the TFP index, statisticians have estimated that less than half of output growth in the U. S. was attributable to growth of the labor force and the economy's stock of capital equipment.

Much work remains to be done in the field of productivity measurement. The statistical information used in the construction of productivity indexes needs to be improved. The TFP measure must be further broken down to yield more precise specifications of the growth forces remaining to be explained after labor and capital growth have been accounted for. Finally, additional investigation is necessary to determine how these residual growth forces are linked to the conventional inputs, labor and capital, and how existing measures of these inputs can be improved to incorporate or embody the residual forces.

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CHECK COLLECTION AND FEDERAL RESERVE FLOAT

The sometimes picturesque jargon of the banker includes terms and phrases that are often a mystery to those not acquainted with the vernacular of the financial community. One such term is "float," which is used to denote the overstatement of deposit liabilities of banks resulting from delays in collecting the multitude of checks written everyday. Because of these delays, and of other details of banking practice in this country, a check drawn on one bank and left for deposit with another bank will often be credited to the depositor's account before a corresponding debit is made to the account of the check writer. The check must be sent from the receiving bank to the drawee bank for collection, and this may require a day or several days. In the interim, the combined deposit accounts of the check recipient and the check writer are overstated by the amount of the check. The overstatement of commercial bank deposit liabilities to the public arising in this fashion is referred to as commercial bank float. It is measured by the dollar volume of checks in one or another stage of transit between banks or, in balance sheet terms, by the entry "cash items in process of collection."

Federal Reserve Float But there is yet another kind of float, similar in nature to commercial bank float but quite different in significance. This is Federal Reserve float, so-called. When a bank that is a member of the Federal Reserve System receives on deposit a check drawn on a bank in another city, it will often send the check to the Federal Reserve Bank of its district for collection, taking payment in the form of a credit to its reserve account. The Reserve Bank will credit the reserve account either immediately, or with a one- or two-day deferral, depending on its so-called "availability schedule" and on the location of the bank on which the check is drawn. In no case is the credit to the reserve account of the sending bank deferred more than two days. In the case of a sizable fraction of the checks sent to the Federal Reserve Banks for collection, the reserve account of the sending bank is credited one or more, sometimes as many as four or five or more, days before a corresponding debit is made to the account of the drawee bank. The combined reserve accounts of the sending bank and the receiving bank are thus increased, temporarily, as the result of the time lag between the credit and the debit, and this increase is what is denoted by the term "Federal Reserve float."

Because, unlike commercial banks, the Federal Reserve Banks do not give immediate credit for all checks sent to them for collection, Federal Reserve float is measured in a manner somewhat different from that used in measuring commercial bank float. In the case of commercial banks, deposit credit has been given for all uncollected items or "cash items in process of collection." Hence, the total of commercial banks' cash items in process of collection represents commercial bank float. For the Federal Reserve Banks, however, reserve account credit has been given only for some uncollected items, with a deferred availability account credited for the others. Hence, to arrive at Federal Reserve float the sum of deferred availability items must be subtracted from the volume of uncollected items.

Importance of Float Commercial bank float, or its balance sheet counterpart, cash items in process of collection, is important to commercial bankers chiefly because it figures in the computation of their reserve requirements. Member banks are allowed to subtract their cash items in process of collection from their gross demand deposits in calculating their legal reserve requirements. In many states, nonmember banks can count cash items along with their correspondent balances as legal reserves. But commercial bank float is also of interest to money and banking students and to monetary policymakers. In calculating the size of the demand deposit component of the money stock, close students of the monetary system conventionally subtract commercial bank float, along with interbank deposits and U. S. Treasury deposits at commercial banks, from gross demand deposits at commercial banks to get a measure of the general public's demand claims on the banking system.

From the standpoint of the monetary authorities, however, Federal Reserve float is more important than commercial bank float. This is true, basically, because Federal Reserve float creates new reserves

for the commercial banking system. This is to say that it creates "high-powered money" that can be used as a basis for multiple expansion of bank credit and demand deposit money. Federal Reserve float is, in a sense, credit extended by the central bank to the commercial banking system and it has the same effect on the reserve base of the banking system as an increase in Federal Reserve discounts and advances. Moreover, Federal Reserve float is one of the most volatile factors affecting member bank reserves and hence basic monetary and credit conditions. It fluctuates sharply from day to day and from week to week and its movement must be followed closely by the central bank in its efforts to preserve orderly credit conditions. Because of the significance of Federal Reserve float in this regard, the remainder of this article is devoted to this category of float.

Four Sources of Federal Reserve Float Federal Reserve personnel involved in the check collection function distinguished four kinds of Federal Reserve float, each associated with a particular cause of delay in the collection process. These are (1) remittance float, (2) time schedule float, (3) transportation float, and (4) holdover float. These several kinds of float, or causes of float, can be explained best against a background description of general Federal Reserve check-handling practices.

Reserve credit for checks received for collection by a Federal Reserve Bank is deferred no more than two business days from the date of receipt. Some checks are payable through the local clearing arrangements of the city in which the Reserve Bank is located. Immediate credit to reserve accounts is given for these if they are received in time to be processed through the clearing house. Some checks payable in other Federal Reserve cities may be credited to reserve accounts in one business day if they are received in time to collect them in the local clearings of these cities.

The vast majority of checks handled by the Reserve Banks, however, are drawn on out-of-town banks, most on so-called "country check" points. Once these checks have reached the Reserve Bank they must be forwarded to drawee banks for collection. If the drawee bank is accessible by surface transportation overnight, it will be charged one day after it receives the checks from the Reserve Bank. This practice is based on transit time required to deliver the checks to their destination and time for payment to be returned to the Reserve bank along with any return items. If surface transportation requires more than one day, or if payment by the bank normally takes more than one day for return to the Reserve Bank, the Reserve Bank delays charging the remitting bank's account.

Many banks are charged by their Federal Reserve Bank under an automatic remittance plan. This plan, however, while automatic, recognizes and preserves the normal transit time required for receipt and payment. In some cases, even within a given Reserve District, the drawee bank is charged three or more days after checks are dispatched by the Reserve Bank, although the Reserve Bank has granted reserve credit *two* days after its receipt. This amount, a net debit on the books of the Fed for one or more extra days, is called "remittance float."

Checks received by a Reserve Bank for collection on country banks in another Federal Reserve territory require one day in transit between Reserve offices and a minimum of two more days after the checks are dispatched to the drawee bank before remittance is made. Since full reserve credit is granted by the first receiving Reserve Bank only two days after its receipt and handling, collection is not generally possible in less than three business days, and float is inevitable even under ideal transportation conditions. This type of float, incurred on almost all interdistrict checks, is referred to as "time schedule float."

Commercial banks customarily receive their greatest daily volume of checks on Monday, which apparently reflects the public's tendency to pay bills on weekends. These checks are largely deposited with Reserve Banks on Tuesday, with credit deferred no later than Thursday. Since many of these checks are interdistrict items, actual collection cannot be obtained from the drawee banks before Friday. Thursday balances on Reserve Banks' books therefore include a significant amount of time schedule float.

Daily and weekly float patterns are affected not only by general business practices but also by Reserve Bank check-handling practices, such as cut-off hours for receiving checks, and by holidays. These patterns become important in the Federal Reserve's efforts to keep abreast of the effect of float on bank reserves. A 1963 study by Irving Auerbach dealt with the effect of these variations on the procedure for forecasting Federal Reserve float.[1] Auerbach's study revealed that within each month float follows a bell-shaped curve with the peak generally occurring about mid-month. One explanation of this time pro-

[1] Irving Auerbach, "Forecasting Float," *Essays in Money and Credit*, New York: Federal Reserve Bank of New York, 1964.

file of float is that business firms typically bill customers at month end, often with ten day discount terms. For this reason payments are heaviest around the tenth of the month. The banking system receives and processes these checks around mid-month. Another type of seasonal bulge in check payments and float was shown to occur in the fall and early winter months, paralleling a seasonal pick-up in business activity.

Holiday mail delays, bad weather, transport schedules, transportation strikes, and processing overloads on Reserve Bank staff are additional sources of float. Transportation float typically occurs when interdistrict items are delayed in transit between Reserve Banks. Missed airline connections, weather-grounded airplanes, and delayed ground delivery connections are causes of transportation float. This source of float is not entirely uncontrollable. By constantly reevaluating and selecting the best available combinations of transportation between Reserve cities, the desired overnight delivery can usually be achieved. The Federal Reserve Bank of Richmond, among others, arranges some truck deliveries of checks from air terminals to the Bank.

Holdover float arises when the checks received and credited to deferred credit availability accounts are so numerous that they cannot be sorted and dispatched by the Reserve Bank on the day of receipt. The size of the check collection staff may be inadequate to handle unusual or peak volume of checks. Holdover checks are delayed in collection from the drawee bank, but this does not affect timing of credit to the depositing member banks' reserve accounts. Holdover float is controllable in the sense that larger or better-trained staffs can be employed in check collection. Sometimes, however, malfunctions in electronic check sorting and processing equipment are a cause of holdover checks. Reserve Banks try to minimize processing backlog, subject to cost limitations established on the basis of historical and interbank expense comparisons. Also, member banks, encouraged by Federal Reserve reimbursement of transportation costs and earlier reserve credit availability, may send checks directly to other Federal Reserve offices. This procedure places the burden of sorting checks on the sending bank and bypasses one Reserve Bank in the collection process, thus cutting overall collection time and reducing holdover potential.

Float Patterns From 1968 to 1970 Float components from early 1968 to late 1970 are illustrated below for the United States and for four selected Federal Reserve offices. Both trends and cross sectional differences among offices appear in the time series of quarterly figures on float per check.

As one might expect, time schedule float looms largest among the categories of United States Federal Reserve float. Its share of the total has declined somewhat since early 1968 principally because of growth tendencies in the other components. Given continuance of the System's policy of deferring country checks a maximum of two days and the general necessity of collecting inter-Reserve office country items over a minimum of three days, time schedule float is likely to retain its prominence. Its irreducible nature is extenuated by its low volatility relative to other float components. It is the variability of check float more than its magnitude that complicates reserve projections and the implementation of monetary policy.

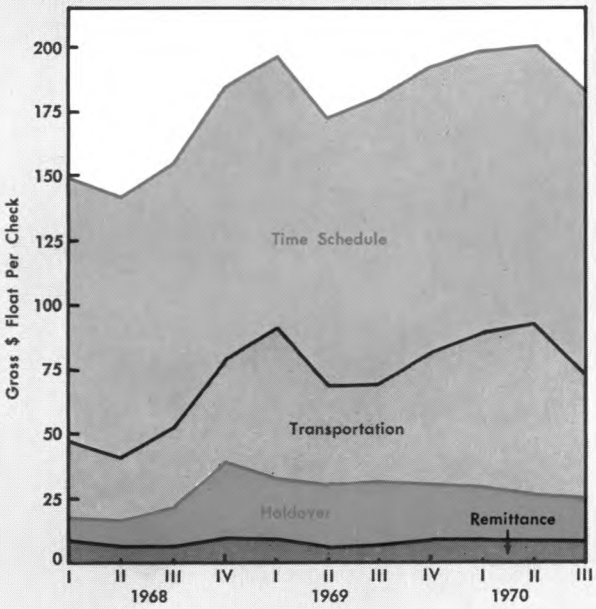
To a small degree, time schedule float may be reduced through improved collection methods. Early dispatch from one Reserve office to another to achieve same-day processing has occurred in some cases. Establishment of regional clearing facilities that encompass portions of two or more Reserve office territories would reduce transit between Reserve offices and consequently would reduce time schedule float. This innovation has occurred in the Washington-Baltimore metropolitan area. The establishment of the Regional Clearing Center in January 1970 produced a noticeable decline in time schedule float at the Richmond office.

Holdover float is largely related to the cost of processing, which, in turn, depends on the quantity of equipment and trained people needed to cope with peak levels of checks processed. For example, the Los Angeles office's total direct costs of processing country checks has consistently been low relative to other Reserve offices' costs. Yet Los Angeles has steadily raised its average holdover backlog in the past three years. Variability in daily check processing volume is also a factor in holdover float. This factor may differ substantially from one Reserve office to another. Given a fixed staff of personnel and equipment, wide variability in daily volume would probably be associated with high levels of holdover float.

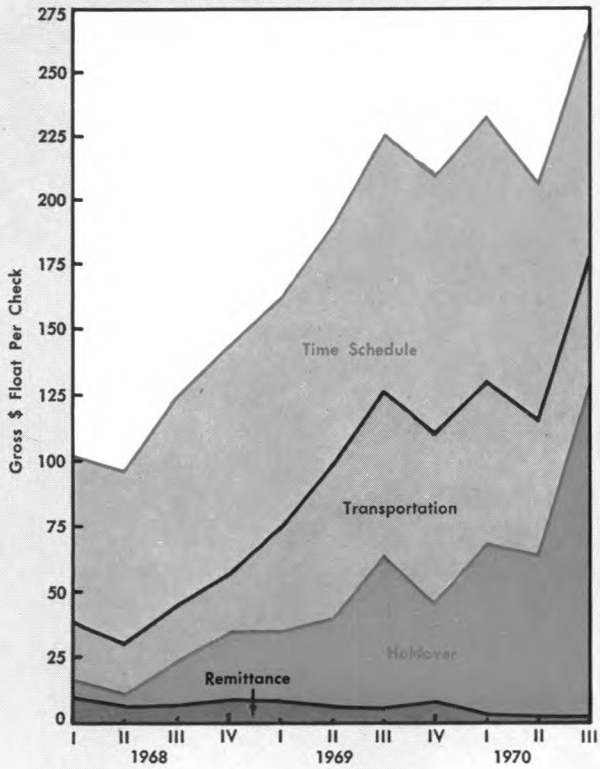
Remittance float is the smallest category of float relative to country check volume. Remittance time is largely related to highway transportation facilities within the Federal Reserve District. The Minneapolis Reserve Bank, with members more geographically dispersed than those in most other Federal Reserve territories, has the greatest proportion of remittance float. Moreover, the end of nonpar banking in Minnesota and the Dakotas in

COMPONENTS OF FLOAT

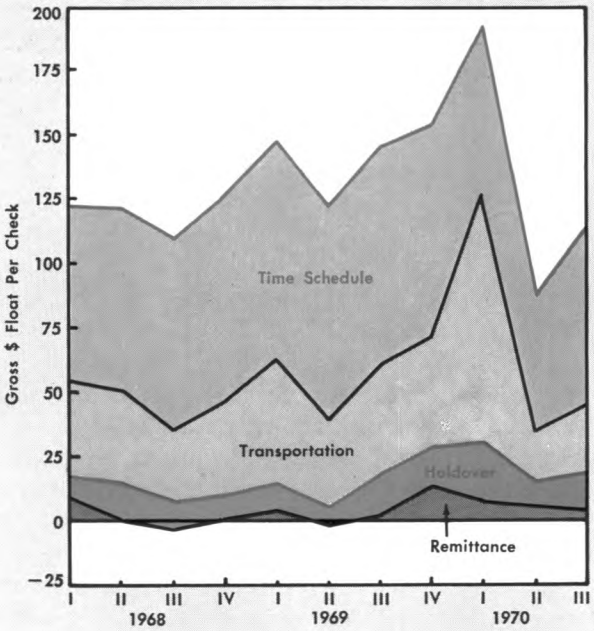
UNITED STATES



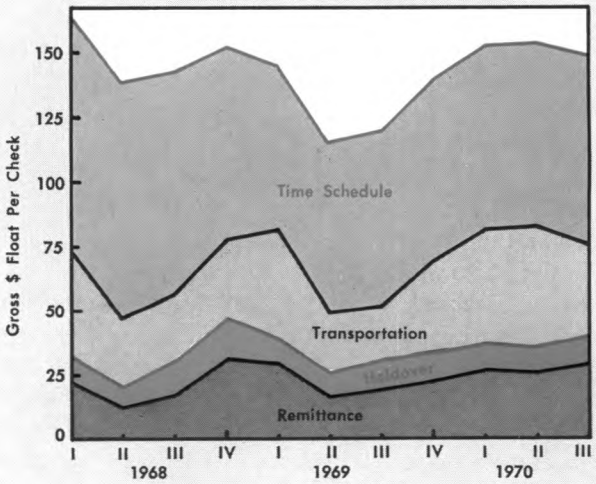
LOS ANGELES FEDERAL RESERVE OFFICE



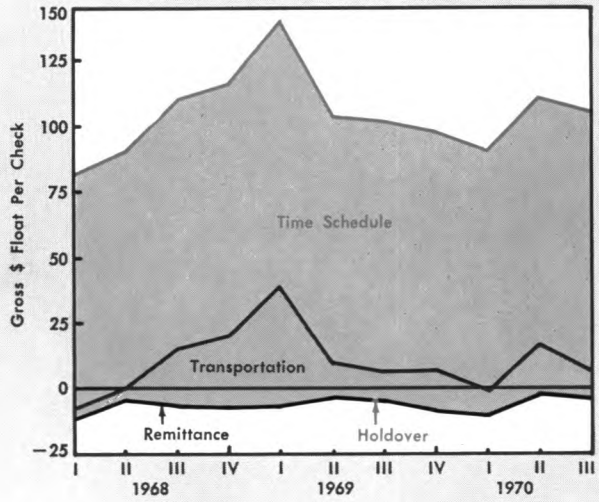
RICHMOND FEDERAL RESERVE OFFICE



MINNEAPOLIS FEDERAL RESERVE OFFICE



CINCINNATI FEDERAL RESERVE OFFICE



1968 added to the number of end points for which check shipments and remittance require more than two days. By contrast, in the Richmond territory, the relative compactness of the area and the prevalence of good road conditions is conducive to a customized contract carrier service at acceptable cost. In the Minneapolis District conditions are not as favorable for substitution of overnight private carrier service for mail service. There are significant numbers of drawee banks dispersed throughout thinly populated areas, and snow removal is a serious problem for some areas. The arrangement of private carrier service to every point would be prohibitively expensive.

Curiously, the Cincinnati Reserve office consistently reports a negative remittance float total. This is attributable to processing and dispatch of checks prior to the date from which deferred credit is calculated. Checks may be received after the Cincinnati bank's deadline for posting deferred credit to the depositing bank's account. Reserve credit, ordinarily deferred two days, is delayed an additional day. The Cincinnati office, nevertheless, dispatches the checks late on the day of receipt. The checks arrive at their destination on the following day and payment is often received the day after that. Hence, payment is obtained prior to the date on which reserve credit is granted.

The Richmond office occasionally has a credit balance in its remittance float account, which is due to Saturday's not being counted as a business day in the deferment of cash items. The Richmond office has a number of drawee banks that are open on Saturday and remit to the Reserve Bank in the form of a draft or charge to a reserve account on Monday. Banks that do not open on Saturday are not charged until Tuesday. Since reserve credit is passed to depositing banks on Tuesday for all country checks received Friday by the Richmond Reserve Bank and some of these checks are actually paid on Monday, a credit balance in the remittance float account occurs.

Transportation float has grown substantially in the float total for the U. S. since early 1968. A seasonal pattern reflecting bad weather and holiday traffic is also apparent. Of all the float developments, the rising trend of transportation float has been most discouraging to nearly all Federal Reserve offices. General air and ground traffic congestion presumably has been responsible for missed connections and increased delivery time. Holdover and remittance float are controllable to some degree; time schedule float, while not subject to control, is less given to the wide variations that complicate aggregate bank reserve projections. Transportation float, however, is only partially controllable; and it is highly variable. The standard handling routines of the U. S. Post Office and the few available private transportation firms are not always sufficiently expeditious for System needs. Constant attention by Reserve bank personnel to changing airline schedules plus pickup and delivery by Reserve Bank trucks has helped. Still, transportation float grows. As yet no satisfactory means of interdistrict check handling comparable to intradistrict carrier schemes has been found.

Conclusion Float could be entirely eliminated in a checkless society. A hundred million account holders could have home and business terminals connected to local and regional computer centers through which payments could be effected with the speed of telephone transmission. Payment and receipt in a given transaction could occur simultaneously.

The disappearance of float would have several policy implications. Reserves formerly granted via float would be replaced by reserves created by Federal Reserve Open Market purchases of securities or by some other means. Commercial banks would no longer need to distinguish collected from uncollected portions of customers' account balances in relating revenues obtained to costs of handling. Bank auditors would not have to distinguish between reserve balances and deferred availability balances in the accounts of member banks. Check "kiting" would be impossible. The monetary authority would not have to take account of changes in reserves occasioned by float nor project variable float effects on reserves. Most importantly, the community would effect its payments without the necessity of handling and shipping tons of paper records.

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