Performance of multifactor productivity in the steel and motor vehicles industries

Over the 1958-84 period, multifactor productivity grew at about half the rate of output per hour in these industries; the ratio of purchased materials, fuels, and services to labor accounted for most of the difference; the capital-labor ratio contributed very little

MARK K. SHERWOOD

For many decades, the Bureau of Labor Statistics has published indexes of output per hour, or labor productivity, for specific industries. It now provides these measures for approximately 150 industries.[1] Movements in output per hour indexes reflect changes in capacity utilization, the composition of the labor force, and technology; economies of scale; research and development; and the substitution of other factors for labor.

A new BLS index, multifactor productivity,[2] relates output to the combined input of capital and intermediate purchases (materials, fuels, electricity, and services) as well as of labor. The movement of this index represents the change in output not accounted for by the directly measurable inputs. The difference between the movement of the multifactor productivity measure and the output per hour measure indicates the impact of changes in the amount of capital services per hour (capital-labor ratio) and the amount of intermediate purchases per hour (intermediate purchases-labor ratio) on output per hour.

This article focuses on the relationship between output per hour and multifactor productivity in the steel and motor vehicles industries. The performances over time of both measures are used to examine the post-1973 slowdown in output per hour in the steel industry (SIC 331). This slowdown coincided with the productivity slowdown that occurred in the major sectors of the economy. The motor vehicles industry (SIC 371) did not experience much of a post-1973 slowdown in output per hour, but the measures help explain that industry's performance. Concepts and methods of deriving the output per hour and multifactor productivity measures are explained in the appendix.

Mark K. Sherwood is an economist in the Office of Productivity and Technology, Bureau of Labor Statistics. John Duke, Lisa Usher, and Jack Veigle, economists in the same office, contributed to the development of the multifactor productivity measures.

The output per hour relationship

Output per employee hour reflects many influences on the use of labor in the production of goods and services in an industry. Two influences are the capital-labor ratio, or capital per hour, and the intermediate purchases-labor ratio, or intermediate purchases per hour. The remaining influences on output per hour movements are also reflected in the multifactor productivity movements. In fact, the multifactor productivity index is actually an index of output per hour adjusted for the influences of capital per hour and intermediate purchases per hour. Indexes of output per hour, multifactor productivity, and related indexes for the steel and motor vehicles industries are shown in table 1.

For both industries, output per hour grew faster during the 1958–84 period than did multifactor productivity. (See chart 1.) The differences in growth rates are accounted for by the capital-labor and intermediate purchases-labor ratios.

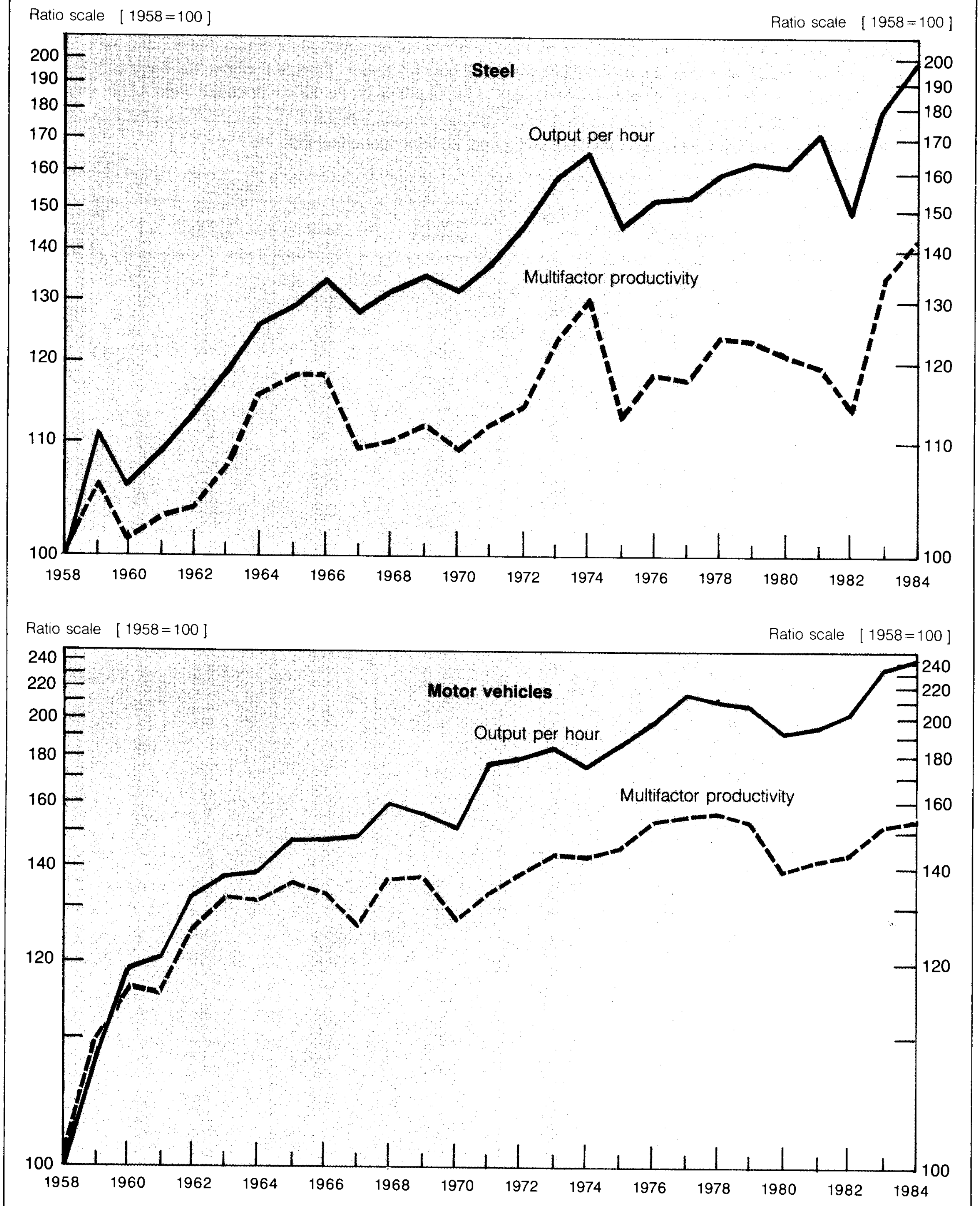
Over the 1958–84 period, the steel industry experienced a 0.7-percent average annual growth in output, while labor hours fell at a 1.9-percent rate. To measure the contribution of capital-labor and intermediate purchases-labor ratios to this output per hour growth, it is necessary to weight the growth rates of these two variables by the respective non-labor input's share of output. For example, the weight applied to the growth of the capital-labor ratio is equal to capital income divided by the value of output. Output per hour is equal to the products of these weights times the growth rates of the explanatory variables plus multifactor productivity. Of the 2.7-percent annual growth in output per hour over the 1958–84 period in the steel industry, 0.1 percent was contributed by capital and 1.2 percent by intermediate purchases. Multifactor productivity grew 1.4 percent.[3]

Although capital's relatively low share reduces the contribution of the capital-labor ratio, the ratio itself grew about 2 percent a year. Capital services did decline from the late 1950's through the first half of the 1980's, but labor hours

Table 1. Productivity and related indexes for the steel and motor vehicles industries, 1958–84
[1977=100]

Year	Productivity		Output	Input			
	Output per hour	Multifactor productivity		Hours of all employees	Capital	Intermediate purchases	Combined units of inputs
Steel:							
1958	65.8	84.9	66.7	101.3	87.7	62.8	78.5
1959	73.0	90.1	76.2	104.5	87.4	72.2	84.6
1960	69.2	86.0	77.1	111.4	88.2	77.7	89.6
1961	71.9	87.4	74.4	103.4	90.0	73.0	85.1
1962	74.0	87.9	76.6	103.6	89.9	76.7	87.2
1963	78.1	91.5	82.1	105.2	89.4	80.9	89.8
1964	82.4	98.0	94.3	114.5	91.0	87.9	96.3
1965	85.3	100.9	102.0	119.6	93.7	93.3	101.1
1966	87.4	100.9	103.3	118.1	97.6	94.8	102.3
1967	84.8	92.9	96.0	113.3	102.8	97.5	103.4
1968	86.4	93.4	100.2	115.9	106.7	102.3	107.3
1969	88.4	94.5	104.3	118.1	108.9	106.3	110.4
1970	86.7	93.0	97.1	112.1	109.6	98.3	104.4
1971	90.7	94.4	92.2	101.7	107.9	92.5	97.7
1972	96.4	96.6	99.3	102.9	105.2	102.2	102.8
1973	103.8	104.0	116.2	111.9	102.9	114.4	111.7
1974	109.4	110.7	122.4	111.9	100.5	113.1	110.5
1975	96.0	95.6	93.0	96.8	100.3	97.0	97.2
1976	99.8	100.8	98.4	98.6	100.5	96.6	97.6
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	105.2	104.8	108.7	103.3	98.8	104.9	103.7
1979	106.6	104.4	111.3	104.5	97.4	109.7	106.6
1980	105.8	102.4	95.3	90.1	95.8	94.6	93.1
1981	112.1	101.6	102.0	91.0	94.3	106.8	100.4
1982	98.1	96.4	66.6	67.9	91.8	68.8	69.1
1983	118.6	113.8	71.8	60.6	88.3	63.6	63.1
1984	130.9	120.4	79.7	60.9	84.6	68.9	66.2
Motor vehicles:							
1958	47.2	64.3	27.7	58.8	76.7	32.0	43.1
1959	51.6	70.5	35.7	69.1	75.6	39.4	50.6
1960	56.1	74.2	40.5	72.1	75.2	44.3	54.6
1961	56.8	73.8	35.1	61.7	72.2	37.6	47.5
1962	62.2	80.4	44.3	71.1	69.4	46.7	55.1
1963	64.9	84.2	49.6	76.5	70.5	50.8	58.9
1964	65.4	83.9	51.0	78.0	74.8	52.2	60.8
1965	69.8	87.1	62.4	89.3	81.4	64.1	71.6
1966	69.8	85.2	62.2	89.1	87.6	64.5	72.9
1967	70.0	81.4	56.6	80.9	91.4	61.1	69.6
1968	76.0	87.8	69.1	90.9	93.9	71.3	78.7
1969	74.4	88.2	68.7	92.3	97.0	68.8	77.8
1970	71.4	81.8	55.8	78.2	99.1	58.7	68.2
1971	83.0	85.6	70.1	84.5	97.0	77.8	81.9
1972	84.7	89.2	76.8	90.6	96.7	82.3	86.1
1973	86.1	92.4	88.2	102.4	100.9	92.1	95.5
1974	82.2	91.5	73.7	89.7	102.7	73.2	80.5
1975	88.1	93.1	68.2	77.4	99.4	67.2	73.2
1976	94.1	97.9	86.0	91.4	96.1	84.8	87.9
1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	99.6	100.1	104.2	104.7	106.3	103.5	104.1
1979	97.5	98.8	96.2	98.7	110.8	94.3	97.3
1980	89.8	89.6	68.9	76.8	111.5	72.5	76.9
1981	92.0	90.3	71.9	78.1	114.3	75.6	79.6
1982	96.2	90.9	65.9	68.5	115.3	68.9	72.5
1983	109.3	96.5	85.1	77.9	106.3	90.7	88.2
1984	113.8	97.5	102.8	90.4	101.8	114.8	105.5

Chart 1. Multifactor productivity and output per hour in the steel and motor vehicles industries, 1958–84



also declined. The myriad factors in multifactor productivity accounted for about half the growth in output per hour.

For the motor vehicles industry, multifactor productivity also grew at about half the rate of output per hour. Of the 3.4-percent growth per year in output per hour over the 1958–84 period, 2.0 percent was contributed by intermediate purchases and −0.1 percent by capital. Multifactor productivity grew 1.6 percent.

Unlike in the steel industry, the capital-labor ratio declined slightly in the motor vehicles industry because growth in labor hours slightly exceeded that in capital services. The capital-labor ratio contributed virtually nothing to the growth in output per hour.

Pre- and post-1973 productivity

Chart 1 reveals that output per hour and multifactor productivity measures exhibit cyclical behavior. To minimize the effect of these cyclical movements on our analysis of productivity trends, we selected time periods beginning and ending with peak levels of output. In the discussion of slowdowns in productivity growth after 1973, two reference periods were constructed, 1960–73 and 1973–78.

In both the steel and motor vehicles industries, output initially peaked in 1960 before turning down, with 1978 the last year of peak production. (See chart 2.) For the steel industry, 1978 and 1979 outputs were similar and were at the highest levels since 1973 and 1974. Output in 1981 and 1984 represented only relative peaks during the precipitous fall after 1979. By 1984, output in the motor vehicles industry had returned to its 1978 level, but it is not yet clear whether that is a turning point.

We chose 1973 as a dividing point for the two periods. This was a year of high output for both industries and is often cited as the year in which productivity began slowing in major sectors of the economy. Thus, to analyze the movements of two important industries' output per hour which underlie the movement at the macro level, the same year was chosen as a dividing point.

It would be preferable to pick an ending year for the second period nearer to 1984. However, as noted, the decline in steel output after 1979 makes such a choice undesirable when trying to abstract from influences associated with low levels of output. Therefore, we chose 1978 as the ending year.

It should be noted that the minimal contribution of the capital-labor ratio on output per hour performance is not sensitive to the selection of these periods. However, the growth rates of the contribution of intermediate purchases per hour and multifactor productivity do not remain constant proportions of the growth rate of output per hour when alternative time periods are selected.

Output per hour. Over the 1960–78 period, output grew at an annual average rate of 1.9 percent for the steel industry and 5.4 percent for the motor vehicles industry. When these rates are compared with the growth rates of employee hours of −0.4 and 2.1 percent, both industries experienced positive growth of output per hour. The following tabulation shows, for the steel and motor vehicles industries, the average annual rates of growth in output per hour, output, and hours over the 1960–78, 1960–73, and 1973–78 periods, and the slowdown between the latter periods:

	1960–78	*1960–73*	*1973–78*	*Slowdown*
Steel:				
Output per hour	2.4	3.2	0.3	−2.9
Output	1.9	3.2	−1.3	−4.5
Hours	−.4	0	−1.6	−1.6
Motor vehicles:				
Output per hour	3.2	3.3	2.9	−0.4
Output	5.4	6.2	3.4	−2.7
Hours	2.1	2.7	.4	−2.3

Between 1973 and 1978, output per hour increased for both industries, but at a lower annual average rate than for the prior 13-year period. In both industries, output growth slowed faster than hours.

The sensitivities of the post-1973 output per hour slowdowns to the choices of the ending year of the second period (1978) and the initial year of the first period (1960) are shown in appendix table A.1. Output per hour in the steel industry slowed regardless of the period compared. For motor vehicles, when the second period ends in high levels of activity in 1977 and 1978 and 1983 and 1984 (periods more relevant for comparison), and when the 1958–73 "trough to peak" performance is ignored, a post-1973 slowdown can be seen to have been relatively small for this industry. The slowdown was somewhat larger when the second period ends in 1984 rather than in 1978.

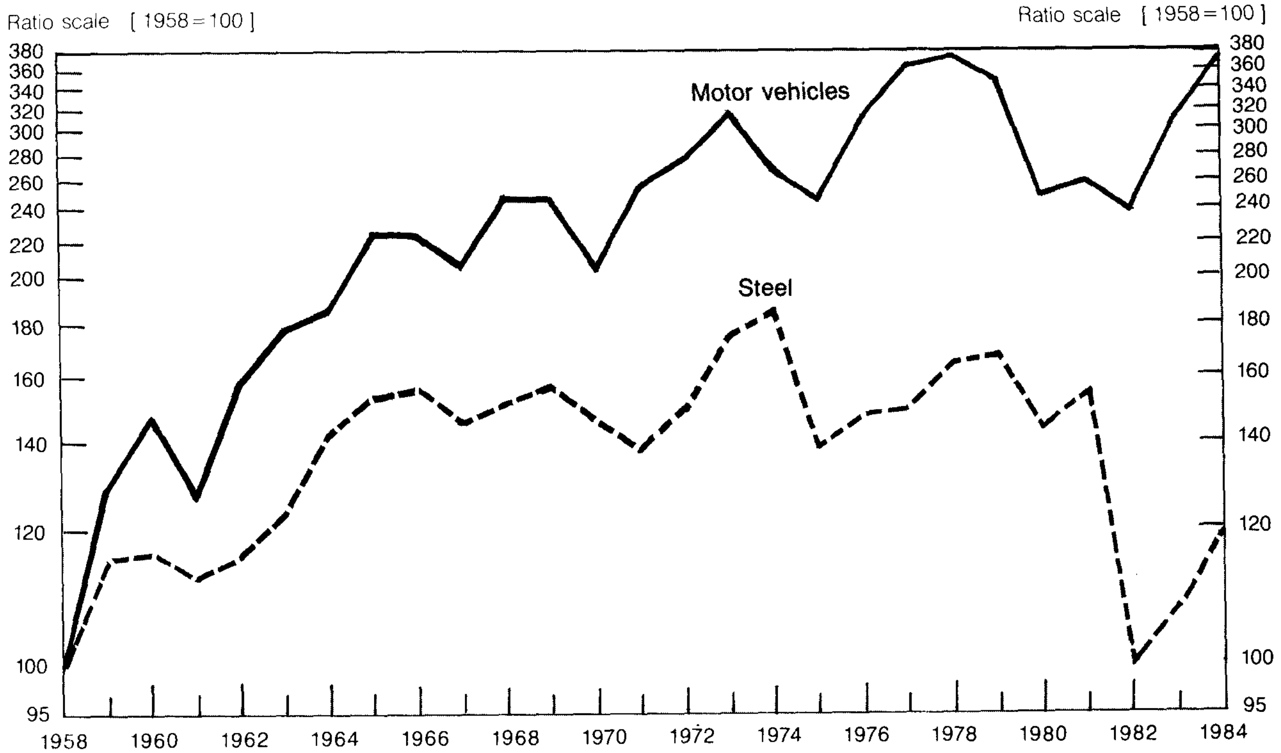
Productivity in steel

Capital per hour. In the steel industry, the growth of capital services fell after 1973, but the growth rate of hours of all employees fell nearly as much. Consequently, capital per hour exhibited only a slight slowdown when the 1973–78 period is compared with the 1960–73 period. When the capital share weight is applied to determine the contribution of capital per hour to the slowdown in output per hour in steel, we find that the role of capital per hour is insignificant. The following tabulation shows the average annual rate of capital per hour in the steel industry for the 1960–78, 1960–73, and 1973–78 periods, and the slowdown between the latter periods:

	1960–78	*1960–73*	*1973–78*	*Slowdown*
Capital per hour	1.1	1.2	0.8	−0.4
Capital services	.6	1.2	−.8	−2.0
Hours	−.4	0	−1.6	−1.6
Contribution of capital to output per hour	.2	.2	.1	−.1

Capital measures require certain methodological choices. The results regarding the capital-labor ratio were tested for

Chart 2. Indexes of output in the steel and motor vehicles industries, 1958–84



sensitivity to the inclusion of land and inventories as part of the aggregate capital services measure, the choice of the age-efficiency function used to compute the productive capital stocks, and the choice of time periods for comparisons.

The capital measures include land and inventories of final products, work in process, and materials in the capital input. We found that growth rates in the comparison periods are affected only slightly by the inclusion or exclusion of land and inventories. (See appendix table A.2.)

The capital measures were derived with four age-efficiency functions. An age-efficiency function is required so that equipment and structures assets of different vintages can be aggregated in a way which reflects possible differences in productive efficiency among capital assets with various vintages. We used the concave form, in which it is assumed that as an asset ages, its efficiency declines at an increasing rate.

Another form, the straight line, assumes that an asset's efficiency decreases by the same amount each year over the life of the asset. The third (gross) assumes an asset loses 100 percent of its efficiency at the end of its life and none before. The fourth is the geometric form in which assets exhibit rapid early service losses followed by more gradual losses of remaining efficiency. The change in the capital-labor ratio based on capital estimated with each of these four age-efficiency functions, when related to the change in the labor input, contributed almost nothing to the post-1973 output per hour slowdown. (See appendix table A.3.)

When the capital-income share weight was applied to the change in any post-1973 rate relative to any pre-1973 rate, the output per hour slowdowns resulting from capital per hour was positive for many periods, and where the contribution was negative, it was not significantly so. (See appendix table A.1 for growth rates of capital per hour for the various periods.)

An important issue remains. The above capital measures and all other measures of capital input for productivity analysis assume a fixed pattern of efficiency loss as assets age. Some analysts have hypothesized that the slowdown in output per hour after 1973 may have been caused by a decrease in the services of capital relative to the measured capital stock.[4] Presumably, the principal reason is increased obsolescence as a result of the sharp rise in oil prices in 1973 and 1979, and the shift of part of capital spending to energy-saving techniques. This hypothesis has been debated in the literature. It is an important issue, and the BLS has undertaken research to measure its significance.

Intermediate purchases per hour. Over the entire 1960–78 period and in both the pre- and post-1973 periods, the growth in real intermediate purchases in the steel industry was similar to output growth. However, the output growth rate was considerably different than the growth in hours over the long-term and in the pre-1973 period. The following tabulation shows average annual rates of growth in output and intermediate purchases per hour in the steel industry for the 1960–78, 1960–73, and 1973–78 periods, and the slowdown between the latter periods:

	1960–78	*1960–73*	*1973–78*	*Slowdown*
Output	1.9	3.2	−1.3	−4.5
Intermediate purchases	1.7	3.0	−1.7	−4.7
Hours	−.4	0	−1.6	−1.6
Intermediate purchases per hour	2.1	3.0	−.1	−3.1
Contribution of intermediate purchases per hour	1.1	1.5	−.1	−1.5

The intermediate purchases-labor ratio grew rather rapidly between 1960 and 1973 and then slowed in the 1973–78 period. The negative growth in hours during the 1960–73 period, combined with the significant growth in intermediate purchases, led to the rapid growth of intermediate purchases per hour. The 1.5-percentage-points slowdown of the contribution of intermediate purchases per hour is quite significant when compared with the 2.9-percentage-points slowdown in output per hour. The post-1973 slowdown in the intermediate purchases-labor ratio is not sensitive to the periods compared; the proportion of the slowdown which is explained by the intermediate purchases per hour slowdown does vary, however. (See appendix table A.1.)

Multifactor productivity. After accounting for the contributions of capital per hour and intermediate purchases per hour to the post-1973 output per hour slowdown, the remainder is the change in multifactor productivity. The following tabulation shows average annual rates of growth in output per hour and its contributory variables and multifactor productivity in the steel industry, 1960–78, and the slowdown between the 1960–73 and 1973–78 periods:

	1960–78	*Slowdown*
Output per hour	2.4	−2.9
Minus:		
Contribution of:		
Capital per hour	.2	−.1
Intermediate purchases per hour	1.1	−1.5
Equals:		
Multifactor productivity	1.1	−1.4

The significant slowdown in multifactor productivity growth suggests that new technologies were introduced rapidly into the industry before 1973, but at a much slower rate after that date. From 1960 to 1973, multifactor productivity grew at an annual average rate of 1.5 percent, but slowed to a 0.1-percent rate during the 1973–78 period, a 1.4-percentage-point slowdown.

Productivity in motor vehicles

The capital-labor ratio played a positive role in the minor slowdown in output per hour growth that occurred in the motor vehicles industry after 1973. The following tabulation shows average annual rates of growth in capital per hour for the motor vehicles industry, 1960–78, 1970–73, and 1973–78, and the slowdown between the latter periods:

	1960–78	*1960–73*	*1973–78*	*Slowdown*
Capital per hour	−0.1	−0.4	0.6	1.0
Capital services	1.9	2.3	1.0	−1.3
Hours	2.1	2.7	.4	−2.3
Contribution of capital per hour	0	−.1	.1	.2

The finding was the same when land and inventories were excluded from the definition of capital. Also, this result occurred in almost all cases when different time periods were selected. Alternative estimates of the growth of capital assuming four different age-efficiency functions showed the same results. (See appendix tables A.2 and A.3.)

Intermediate purchases per hour increased over the 1960–78 period for motor vehicles. This growth slowed after 1973, and did not contribute positively to output per hour growth. In almost all cases, a post-1973 slowdown in intermediate purchases per hour is not sensitive to the choice of time periods. But the proportion of output per hour slowdown explained by intermediate purchases varies. (See appendix table A.1.)

An example of why intermediate purchases per hour does not contribute a constant proportion to output per hour growth can be seen in the following tabulation which shows average annual rates of growth in output and intermediate purchases per hour in the motor vehicles industry for the 1960–78, 1960–73, and 1973–78 periods, and the slowdown between the latter periods:

	1960–78	*1960–73*	*1973–78*	*Slowdown*
Output	5.4	6.2	3.4	−2.8
Intermediate purchases	4.8	5.8	2.4	−3.4
Hours	2.1	2.7	.4	−2.3
Intermediate purchases per hour	2.7	3.0	1.9	−1.1
Contribution of intermediate purchases per hour	1.6	1.7	1.2	−.6

Intermediate purchases did not grow at a similar rate as output in all periods. For the pre-1973 period, it grew at a similar rate, but after 1973, at a slower rate. This difference in growth rates of output and intermediate purchases between 1973 and 1978 might be at least partially explained by changes in the materials requirements of the motor vehicles industry resulting from the resizing of automobiles after 1973.

Multifactor productivity grew at nearly identical rates before and after 1973. The following tabulation shows average annual rates of growth in output per hour and its contributory variables and multifactor productivity in the motor vehicles industry, 1960–78, and the slowdown between the 1960–73 and 1973–78 periods:

	1960–78	*Slowdown*
Output per hour	3.2	−0.4
Minus:		
Contribution of:		
Capital per hour	0	.2
Intermediate purchases per hour	1.6	−.6
Equals:		
Multifactor productivity	1.7	0

Sensitivity of multifactor productivity to time

For both the steel and motor vehicles industries, the selection of pre-1973 and post-1973 time periods does affect the relative magnitudes of multifactor productivity slowdowns. In the preceding analysis, multifactor productivity slowed by a little less than half the percentage-points slowdown in output per hour in the steel industry and not at all for motor vehicles, where output per hour slowed by 0.4 points. This is not always the case. (See appendix table A.1.)

The reason for this sensitivity can be seen by viewing multifactor productivity growth as the residual of output per hour less the contributions of capital per hour and intermediate purchases per hour. As discussed, these contribution terms do not grow such that they contribute constant proportions to the growth of output per hour. Thus, multifactor productivity need not grow in a fixed proportion to output per hour growth.

Summary: performance of the variables

Over the last quarter of a century, output per hour grew at an annual rate of about 2.5 percent in the steel industry and at a rate of about 3.5 percent in motor vehicles. Multifactor productivity increased at about one-half the rate of output per hour in each industry. The capital-labor ratio contributed little to the industries' output per hour performances. Intermediate purchases per hour contributed about one-half to the growth.

The interpretation of changes in the ratio of a nonlabor input to labor is difficult. There are several factors which can affect this ratio. For example, in the case of intermediate purchases per hour, an industry may choose to purchase more processed materials rather than use its own labor to carry out the processing (that is, a change in vertical integration). Also, the industry may use its intermediate purchases more efficiently in the production process. The ratio is also affected by factors such as technology changes which alter the labor requirements, but not the intermediate purchases requirements, in an industry's production process.

Output per hour in these industries did not grow at the same rate before and after 1973. After accounting for cyclical movements in output, the annual average rate was almost 3 percentage points less after 1973 for steel; about a half percentage point less for motor vehicles.

The impact of capital growth on these industries' output per hour performances after 1973 was minor. Although the rate of growth of capital services slowed for both industries, the growth of hours of all employees also slowed. Thus, the relative performance of the capital-labor ratios after 1973 contributed little to the post-1973 productivity slowdowns.

In general, intermediate purchases per hour contributed significantly to the performance of output per hour after 1973. For most of the post-1973 period, multifactor productivity slowed for both industries; any speedups in growth were generally small. □

——*FOOTNOTES*——

[1] For the latest indexes, see Arthur Herman, "Productivity gains continued in many industries during 1985," *Monthly Labor Review*, April 1987, pp. 48–52.

[2] See Jerome A. Mark and William H. Waldorf, "Multifactor productivity: a new BLS measure," *Monthly Labor Review*, December 1983, pp. 3–15.

[3] For growth rates presented in this article, the sums of components may not equal totals due to rounding.

[4] See, for example, Martin N. Baily, "Productivity and the Services of Capital and Labor," *Brookings Papers on Economic Activity*, vol. 1, 1981, pp. 1–66.

APPENDIX: Multifactor productivity measurement

The index formulation for multifactor productivity measurement, including the weighting scheme to combine various inputs, can be derived by postulating a very general relationship between output and inputs. By adding two assumptions regarding the markets in which the inputs are purchased as well as the economies of scale associated with an industry, it is possible to calculate the indexes with discrete data on prices and real levels of inputs and output.

The general form of the production function underlying the multifactor productivity measures is postulated as:

$$Q(t) = Q(K(t), L(t), M(t), t) \tag{1}$$

where Q(t) is total output, K(t) is input of capital services, L(t) is input of labor services, M(t) is input of intermediate purchases, and t is time.

Differentiating equation (1) with respect to time and with some algebraic manipulations, the sources of growth equation is:

(2) $\dot{Q}/Q = a + w_k \cdot \dot{K}/K + w_l \cdot \dot{L}/L + w_m \cdot \dot{M}/M$

where a is the rate of change of multifactor productivity, w_k is output elasticity (percentage change in output due to a 1-percent change in input) with respect to the capital input, w_l is output elasticity with respect to the labor input, and w_m is output elasticity with respect to the intermediate purchases input (the dot over a variable indicates the derivative of the variable with respect to time).

Equation (2) shows the rate of change of output as the sum of the rate of change of multifactor productivity and a weighted average of rates of change of capital, labor, and intermediate purchases inputs. Now, if competitive input markets are assumed, then each input is paid the value of its marginal product. The output elasticities in equation (2) can then be replaced by factor income shares:

$$w_k = P_k \cdot K/P_q \cdot Q$$
$$w_l = P_l \cdot L/P_q \cdot Q, \text{ and}$$
$$w_m = P_m \cdot M/P_q \cdot Q$$

where P_q is the price of output, and P_k, P_l, and P_m are the prices paid for the capital, labor, and intermediate purchases inputs, respectively. Furthermore, if constant returns to scale are assumed, then $w_k + w_l + w_m = 1$.

Equation (2) can be rewritten as:

(3) $a = \dot{Q}/Q - w_k \cdot \dot{K}/K - w_l \cdot \dot{L}/L - w_m \cdot \dot{M}/M$

In this expression, the growth of multifactor productivity can be seen as a measure of economic progress; it measures the increase in output over and above the increase simply due to increases in inputs.

Equation (2) can also be transformed into the contribution equation which allows for an analysis of the change in output per hour. First, subtract $\dot{L}/L$ from both sides of equation (2). Because the weights sum to one, apply the term $(w_k + w_l + w_m)$ to the $\dot{L}/L$ term inserted on the right side. Next, gather terms with the same weight and derive the following equation.

(4) $\dot{Q}/Q - \dot{L}/L = w_k(\dot{K}/K - \dot{L}/L) + w_m(\dot{M}/M - \dot{L}/L) + a$

The left side of equation (4) is the growth rate of output per hour. The terms in brackets are the rates of change in the capital-labor ratio and the intermediate purchases-labor ratios. Thus, the rate of growth in output per hour can be decomposed into the weighted sum of changes in these ratios plus the change in multifactor productivity. (When compound growth rates are used, as in the text, mathematically, the sum of rates for the contribution terms plus multifactor productivity need not exactly equal the rate of growth of output per hour. For the analysis in this article, except for rounding differences, they were equal.)

Equations (2), (3), and (4) are Divisia indexes which require continuous data for computation. The BLS multifactor indexes are actually constructed according to a Tornquist formula which represents a discrete approximation to the Divisia index. The rate of change in output or in an input is calculated as the difference from one period to the next in the natural logarithms of the variables. For example, $\dot{Q}/Q$ is calculated as $\ln Q(t) - \ln Q(t-1)$. Indexes are constructed as the antilogarithms of this differential. In construction, the weights w_k, w_l, and w_m are calculated as the arithmetic averages of the respective shares in time periods t and $t - 1$.

Concepts and calculations

The following is a brief summary of the concepts and methods underlying the multifactor productivity measures. More detail is available from the author at the Bureau of Labor Statistics, Washington, DC 20212.

Output. For the new industry level measures, output is defined as total production, rather than the commonly employed alternative of value added. For a value-added measure, intermediate inputs are subtracted from total production. Consequently, an important difference between the industry level measures and the multifactor productivity indexes BLS publishes for aggregate sectors of the economy is that the major sector measures are constructed within a value-added framework. For the major sectors of the economy, intermediate transactions tend to cancel out.

Further, output in these new measures is defined as total production which "leaves" an industry in a given year in the form of shipments plus net changes in inventories of finished goods and work in process. Shipments to other establishments within the same industry are excluded because they represent double counting which distorts the productivity measures. Double counting is present in output (and cost of materials) measures derived from certain data series.

The motor vehicles output measure is based on the output measure from the output per employee hour series which the BLS publishes for this industry. The steel output measure is primarily constructed as the value share weighted change in the quantities shipped of approximately 80 steel products which are available annually in the Bureau of the Census' *Current Industrial Reports*, MA33-B series. The quantity series used is "net" shipments which does not include intraindustry transactions in steel products.

Labor. Employee-hour indexes, which represent the labor input, measure the aggregate number of employee hours. For both the steel and motor vehicles industries, hours for production and nonproduction workers are taken from the published BLS output per hour series.

Capital. A broad definition of capital input, including equipment, structures, land, and inventories, is used to measure the flow of services derived from the stock of physical assets. Equipment and structures assets here are comprised of 19 classes of assets. Financial assets are not included.

For productivity measurement, the appropriate concept of capital is "productive" capital stock, which represents the stock used to produce the capital services employed in current production. To measure the productive stock, it is necessary, for each type of asset, to take account of the loss of efficiency of the asset as it ages. That is, assets of different vintages have to be aggregated. For the measures in this article, a concave form of the age/efficiency pattern (slower declining efficiency during earlier years) is chosen.

In combining the various types of capital stock, the weights applied are implicit rental prices of each type of asset. They reflect the implicit rate of return to capital, the rate of depreciation, capital gains, and taxes. (For an extensive discussion of capital measurement, see *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178, Bureau of Labor Statistics, 1983.)

Intermediate purchases. Intermediate purchases primarily includes materials, fuels, electricity, and purchased business services. Materials measured in real terms refer to items consumed or put into production during the year. Freight charges and other direct charges incurred by the establishment in acquiring these materials are also included. The data from which the intermediate inputs are derived include all purchased materials and fuels regardless of whether they were purchased by the individual establishment from other companies, transferred to it from other establishments of the same company, or withdrawn from inventory during the year. Consequently, the same issue of double counting noted for the output component is present in the data. An estimate of intraindustry transactions is removed from materials and fuels.

Annual estimates of the cost of services purchased from other business firms are also required for multifactor productivity measurement in a total output framework. Some examples of services are legal services, communications services, and repair of machinery. An estimate of the constant dollar cost of these services is included in the intermediate purchases input.

Capital, labor, and intermediate purchases income shares. Weights are needed to combine the indexes of the major inputs into a combined input measure. The weights for these new measures are derived in two steps. First, an estimate of income in current dollars for each input is derived. Second, the income of an input is divided by the total income of all inputs.

Sensitivity results

Table A.1. Average annual growth rates for output per hour, capital-labor and intermediate purchases-labor ratios, and multifactor productivity, steel and motor vehicles industries, 1958–84

[In percent]

Period	Steel				Motor vehicles			
	Output per hour	Capital to labor ratio	Intermediate purchases to labor ratio	Multifactor productivity	Output per hour	Capital to labor ratio	Intermediate purchases to labor ratio	Multifactor productivity
Pre-1973:								
1958–73 . . .	3.1	0.4	3.4	1.4	4.1	−1.9	3.4	2.4
1959–73 . . .	2.6	.7	2.8	1.0	3.7	−.7	3.3	1.9
1960–73 . . .	3.2	1.2	3.0	1.5	3.3	−.4	3.0	1.7
1961–73 . . .	3.1	.5	3.1	1.5	3.5	−1.4	3.3	1.9
1962–73 . . .	3.1	.5	3.0	1.5	3.0	.1	2.9	1.3
1963–73 . . .	2.9	.8	2.9	1.3	2.9	.7	3.1	.9
1964–73 . . .	2.6	1.6	3.2	.7	3.1	.3	3.3	1.1
1965–73 . . .	2.5	2.0	3.4	.4	2.7	1.0	2.9	.7
1966–73 . . .	2.5	1.5	3.5	.4	3.1	0	3.2	1.2
Post-1973:								
1973–77 . . .	−.9	2.1	−.6	−1.0	3.8	.4	2.7	2.0
1973–78 . . .	.3	.8	−.1	.1	2.9	.6	1.9	1.6
1973–79 . . .	.4	.2	.4	.1	2.1	2.2	1.0	1.1
1973–80 . . .	.3	2.1	.4	−.2	.6	5.7	.7	−.4
1973–81 . . .	1.0	1.5	1.7	−.3	.8	5.1	.9	−.3
1973–82 . . .	−.6	4.4	−.1	−.8	1.2	6.1	1.2	−.2
1973–83 . . .	1.3	4.7	.3	.9	2.4	3.3	2.6	.4
1973–84 . . .	2.1	3.8	.9	1.3	2.6	1.2	3.2	.5

Table A.2 Average annual rates of growth including and excluding selected assets from capital input measures, steel and motor vehicles industries, selected periods, 1960–78

Measure and period	Steel: Total	Steel: Total, excluding— Land	Steel: Total, excluding— Inventories	Steel: Total, excluding— Land and inventories	Motor vehicles: Total	Motor vehicles: Total, excluding— Land	Motor vehicles: Total, excluding— Inventories	Motor vehicles: Total, excluding— Land and inventories
Growth of capital services:								
1960–78	0.6	0.7	0.7	0.8	1.9	2.0	1.3	1.2
1960–73	1.2	1.3	1.2	1.3	2.3	2.3	1.5	1.5
1973–78	−.8	−.8	−.7	−.7	1.0	1.1	.5	.5
Capital services per hour:								
1960–78	1.1	1.1	1.1	1.2	−.2	−.1	−.8	−.9
1960–73	1.2	1.3	1.2	1.3	−.4	−.4	−1.2	−1.2
1973–78	.8	.8	.9	.9	.6	.7	.1	.1

Table A.3. Sensitivity of capital services measures to relative efficiency assumptions, steel and motor vehicles industries, selected periods, 1960–78

[In percent]

Measure and period	Steel: Hyperbolic	Steel: Geometric	Steel: Gross	Steel: Straight line	Motor vehicles: Hyperbolic	Motor vehicles: Geometric	Motor vehicles: Gross	Motor vehicles: Straight line
Capital services:[1]								
1960–78	0.6	0.5	0.9	0.5	1.9	2.3	1.9	2.0
1960–73	1.2	.8	1.5	1.0	2.3	2.6	2.3	2.4
1973–78	−.8	−.3	−.5	−.9	1.0	1.5	.9	1.1
Capital per hour:								
1960–78	1.1	.9	1.4	.9	−.2	.2	−.2	−.1
1960–73	1.2	.7	1.4	1.0	−.4	−.1	−.4	−.3
1973–78	.8	1.3	1.2	.7	.6	1.0	.4	.7

[1] Includes services from equipment, structures, land, and inventories.

Kravis awarded Shiskin prize

Irving B. Kravis, professor of economics at the University of Pennsylvania, received the eighth annual Julius Shiskin Award for Economic Statistics for his work in comparative studies of national income and prices. The presentation was made at the Washington Statistical Society's annual dinner in June, along with an honorarium of $250. The award is named in honor of the ninth U.S. Commissioner of Labor Statistics

The award program is designed to honor unusually original and important contributions in the development of economic statistics or in the use of economic statistics in interpreting the economy. Participating organizations in the program are the Bureau of Labor Statistics, Bureau of the Census, Bureau of Economic Analysis, Office of Federal Statistical Policy and Standards, National Bureau of Economic Research, National Association of Business Economists, and the Washington Statistical Society, with all of which Shiskin was associated during his long career.