Chapter 11.
Industry Productivity Measures

Background

Studies of output per hour in individual industries have been a part of the BLS program since the 1800s. A study of 60 manufacturing industries, prompted by congressional concern that human labor was being displaced by machinery, was released as *Hand and Machine Labor* in 1898. This report provided striking evidence of the savings in labor resulting from mechanization in the last half of the 19th century. The effects of productivity advance upon employment remained an important focus of BLS throughout the 1920s and 1930s. Also during this period, the Bureau began the preparation and publication of industry indexes of output per hour, which were based on available production data from the periodic *Census of Manufactures* and employment statistics collected by BLS.

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

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

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

The industry studies cover a variety of manufacturing and nonmanufacturing industries at the 2-, 3-, and 4-digit Standard Industrial Classification levels. Measures for over 175 industries are published on an annual basis and are provided for periods beginning as early as 1947 and continuing through the most recent year for which data are available. Coverage includes industries in the manufacturing, mining, trade, transportation, communication, public utilities, finance, and business and personal services sectors.

In addition to measures of industry labor productivity, BLS also publishes multifactor productivity statistics for certain industries. Industry multifactor productivity measures, which were first released in 1987, relate output to the combined inputs of labor, capital, and intermediate purchases. Multifactor productivity is free of the effects of changes in the ratio of capital to labor and the ratio of intermediate purchases to labor, whereas labor productivity reflects these changes; hence, multifactor productivity is preferred to labor productivity as a measure of efficiency. However,

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because of the enormous data requirements for the measurement of capital and intermediate purchases, a limited number of industry multifactor productivity measures has been published.

Labor Productivity Measures

Concepts

The indexes of output per hour measure the changes in the relationship between output and the hours expended in producing that output. To calculate a labor productivity index, an index of industry output is divided by an index of hours:

where: $$\frac{Q_t}{Q_o} \div \frac{L_t}{L_o}$$

$\frac{Q_t}{Q_o}$ = the index of output in the current year,

$\frac{L_t}{L_o}$ = the index of labor input the current year,

t = the current year, and

o = the base year.

For an industry producing a single uniform product or service, the output index is simply the ratio of the number of units produced in the current year divided by the number of units produced in the base year. Similarly, the employee hour index equals hours expended in the current year divided by hours expended in the base year.

More typically, industries produce a number of different products or perform a number of different services. For these industries, output is calculated with a Tornqvist formula:

$$\frac{Q_t}{Q_{t-1}} = \exp\left[\sum_{i=1}^{n} w_{i,t}\left(\ln \frac{q_{i,t}}{q_{i,t-1}}\right)\right]$$

where:

$\frac{Q_t}{Q_{t-1}}$ = the ratio of output in the current year (t) to previous year (t-1)

n = number of products,

$\ln\frac{q_{i,t}}{q_{i,t-1}}$ = the natural logarithm of the radio of the quantity product *i* in the current year to the quantity in the previous year, and

$w_{i,t}$ = the average value share weight for product *i*

The average value share weight for product j is computed as:

$$w_{j,t} = \left(s_{j,t} + s_{j,t-1}\right) \div 2$$

where: $$s_{j,t} = p_{j,t}\, q_{j,t} \div \left(\sum_{i=1}^{n} p_{i,t}\, q_{i,t}\right)$$

and $p_{i,t}$ = price of product *i* at time *t*

The Tornqvist formula yields the ratio of output in a given year to that in the previous year. The ratios arrived at in this manner then must be chained together to form a series. If t = 3 and the base year is denoted by *o*, then

$$\frac{Q_t}{Q_o} = \frac{Q_3}{Q_o} = \left(\frac{Q_3}{Q_2}\right)\left(\frac{Q_2}{Q_1}\right)\left(\frac{Q_1}{Q_o}\right)$$

The resulting chained output index, $\frac{Q_t}{Q_o}$, is used in the productivity formula. The employee hour index for an industry with multiple products is calculated in the same manner as in the single-output case.

The measures of output per hour relate output to one input—labor time. They do not measure the specific contribution of labor, capital, or any other factor of production. The measures reflect the joint effect of a number of interrelated influences such as changes in technology, capital investment per worker, capacity utilization, intermediate inputs per worker, layout and flow of material, skill and effort of the work force, managerial skill, and labor-management relations.

Methods and Sources

Output

Industry output indexes are developed from data collected by the Bureau of the Census and other sources. Output indexes are developed as a deflated value of production or physical quantity of production of an industry. Each of these methods is discussed in turn.

Deflated value output indexes. More than two-thirds of the industry output indexes are derived from data on the value of industry output adjusted for price change. The adjustment for price change is accomplished by dividing the value of output by a price index and is known as a *deflated value* method. The resulting indexes are conceptually equivalent to indexes that are developed using data based on physical quantities of products.

To make maximum use of the comprehensive data from the Economic Censuses, output indexes are first derived from data for two consecutive quinquennial censuses; these indexes are referred to as benchmark indexes. Annual indexes for intercensal years are adjusted to the benchmark levels for the census years.

Benchmark indexes. For manufacturing industries, with the deflated-value methodology, current-dollar values of shipments are deflated with appropriate price indexes for each of the 5-digit product class groups, resulting in quantity indexes. The Tornqvist formula presented above is used in the computation of the real-value-of-shipments index for the industry. Additionally, to arrive at the final benchmark output index of production, adjustments are made to reflect net changes in inventories, changes in industry coverage, resales, and intraindustry transfers. Benchmark indexes are developed every 5 years, based on data from *Census of Manufactures.*

For trade industries, benchmark indexes are computed from sales data reported in the *Census of Retail Trade*. Current-dollar sales are deflated with appropriate price indexes for each category of merchandise in the industry, yielding constant-dollar sales. The Tornqvist formula is then used to calculate the real sales index for the industry. Additionally, to arrive at the final benchmark output index of production, an adjustment is made to reflect changes in industry coverage. Benchmark indexes are developed every 5 years, based on data from the *Census of Retail Trade*.

Benchmark indexes for the services industries are computed from data reported in the *Census of Service Industries*. The methodology is similar to that used in developing the indexes for the retail trade industries.

Benchmark indexes for the mining industries are computed from data reported in the *Census of Mineral Industries.*

Annual indexes. For manufacturing industries, the value of shipments for each 5-digit primary product (wherever made) is deflated by an appropriate price index. BLS producer price indexes (PPI's) matching these 5-digit product classes are used if available. If these price indexes are not available, deflators are developed by weighting together more detailed PPI's with base-year value of shipments weights. For recent years, industry PPI's have been available for over 90 percent of manufacturing industries. The Tornqvist formula presented above is used in the calculation of the real value-of-shipments index for the primary products of the industry.

For each year, special coverage ratios for the industry (total value of industry shipments of all products to total value of primary products, wherever made) are used to adjust the wherever-made indexes to the industry basis. The resultant industry indexes are further adjusted to reflect changes in inventories. These adjustments yield the estimated industry indexes of production.

For industries in trade and services, data on the value of sales for each year are divided by an industry price index to derive a measure of the change in the industries' real output. These industry price indexes are, for the most part, producer and consumer price indexes developed by BLS. In the case of retail trade industries, the industry price index is developed by combining current-year consumer price indexes with weights based on sales for each category of merchandise in Census years.

Physical quantity output indexes. Physical quantity output indexes are, where possible, a Tornqvist aggregation of quantities of component products. The basic data on quantities are generally primary products of an industry classified into product groups. The finest level of detail is used. For some industries, the annual indexes are adjusted to deflated-value benchmark indexes by linear interpolation. The indexes for both the annual and benchmark series are developed using the Tornqvist procedure.

Data for the physical quantity output indexes come from numerous sources, including the U.S. Departments of Commerce, Energy, and Transportation and reports from various trade associations. Physical quantity output indexes are used primarily for the mining and transportation industries, and for raw commodity manufactured products.

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

Data from the Bureau of the Census, U.S. Department of Commerce, are used extensively in developing output statistics for manufacturing, trade, and services industries. The U.S. Geological Survey compiles most of the information for the mining and cement industries. Other important Government sources include the U.S. Departments of Energy, Agriculture, Transportation, and Housing and Urban Development, and the Federal Railroad Administration, the Federal Reserve Board, and the Federal Deposit Insurance Corporation. Important sources of trade association data include the Textile Economics Bureau, Inc., National Association of Hosiery Manufacturers, Inc., National Canners Association, Rubber Manufacturers Association, the American Iron and Steel Institute, Association of American Railroads, Ward's Communications, Rice Miller's Association, National Automobile Dealers Association, Pharmaceutical Manufacturers Association, American Bus Association, International Sleep Products Association, American Truck Association, American Paper Institute, Anti Friction Bearing Manufacturers' Association, Fiber Box Association, Institutional Furniture Manufacturers' Association, VISA-CARD Network and Interbank Card Network Association, National Automated Clearing House Association, Agricultural Chemicals Association, Association of Oil Pipelines, and the American Gas Association.

Labor input

The labor input indexes are developed by dividing the aggregate employee hours for each year by the base-period aggregate. Because of data limitations, employee hours are treated as homogeneous and additive with no distinction made between hours of different groups of employees. For industries in which the self-employed are important, indexes are constructed for the hours of all persons, which includes paid employees, partners, proprietors, and unpaid family workers.

Industry employment and employee hour indexes are developed from basic data compiled by the Bureau of Labor Statistics and the Bureau of the Census. For most private nonagricultural industries, BLS publishes employment and average weekly hours data for production or nonsupervisory workers and employment data for all employees. The Bureau of the Census publishes employment and aggregate hours data for production workers and employment data for all employees.

BLS and the Bureau of the Census differ in their definition of employee hours and in their sampling and reporting methods. In general, BLS data are the preferred source for measuring industry employment and hours. Census employment is the sum of an average of production workers plus the number of other employees in mid-March. The average of production workers is the average for the payroll periods for the 12th of March, May, August, and November. In contrast, the BLS employment statistics program (790 Survey) collects employment and hours monthly and the employment levels are benchmarked each year to comprehensive data from the State unemployment insurance programs. (See chapter 2.)

Only employment data are available for nonproduction workers. The average annual hours of these workers must be estimated. The estimates of aggregate nonproduction worker employee hours for the manufacturing industries are derived from published employment data, and estimates of average annual hours per nonproduction worker.

Prior to 1968, the estimates of average annual hours worked were calculated by multiplying the number of workweeks in the year times the scheduled weekly hours. From 1968 to 1977, the estimates of average annual hours for nonproduction workers were based on data collected in the BLS biennial surveys of employee compensation in the private nonfarm economy. Since these surveys are no longer conducted, the 1977 levels of average annual hours per nonproduction worker are being carried forward until other data become available.

For the mining industries, estimates for the hours of nonproduction workers are based on data collected by the Mine Safety and Health Administration. For the trade and services industries, estimates are made for the hours of partners, proprietors, and unpaid family workers using unpublished data collected in the Current Population Survey, and for supervisory workers using data from the *Census of Population*.

All employee hours estimates for manufacturing industries are derived by summing the aggregate hours for production workers and the estimated aggregate hours for nonproduction workers. For trade and services industries, all-person hours estimates are derived by summing the aggregate hours for paid employees and the estimated aggregate hours for partners, proprietors, and unpaid family workers.

Multifactor Productivity Measures

Concepts

The industry multifactor productivity indexes calculate productivity growth by measuring changes in the relationship between the quantity of an industry's output and the quantity of inputs consumed in producing that output, where measured inputs include capital and intermediate purchases (including raw materials, purchased services, and purchased energy) as well as labor input.

A Tornqvist index is used to calculate multifactor productivity:

$$\ln\left(\frac{A_t}{A_{t-1}}\right)=\ln\left(\frac{Q_t}{Q_{t-1}}\right)-\left[w_k\left(\ln\frac{K_t}{K_{t-1}}\right)+w_l\left(\ln\frac{L_t}{L_{t-1}}\right)+w_{ip}\left(\ln\frac{IP_t}{IP_{t-1}}\right)\right]$$

where:

ln = the natural logarithm of the variable
A = multifactor productivity
Q = output
K = capital input
L = labor input
IP = intermediate purchases input

w_k, w_l, w_{ip} = cost share weights

The weights are the means of the cost shares in two adjoining time periods.

$$w_i = \frac{(s_{i,t} + s_{i,t-1})}{2}$$

where:

$$s_{i,t} = \frac{p_{i,t}\, x_{i,t}}{\Sigma\,(p_{i,t}\, x_{i,t})}$$

$p_{i,t}$ = price of input x_i in period t

The Tornqvist formula yields growth rates which are differences in logarithms. The antilogs of these rates are chained to form the index.

Methods and Sources

Output

The output measures used in the industry labor productivity measures are also used in the multifactor productivity measures.

Employee hours

Employee hour indexes are calculated in the same way as those used in measuring industry labor productivity.

Capital

The measure of capital input is based on the flow of services derived from the stock of physical assets. Physical capital is composed of equipment, structures, land, and inventories. Financial capital is excluded. Capital services are estimated by calculating capital stocks; changes in the stocks are assumed proportional to changes in capital services for each asset. Stocks of different asset types are Tornqvist-aggregated, using estimated rental prices to construct the weights for assets of different types.

Capital stocks are calculated using the perpetual inventory method, which takes into account the continual additions to and subtractions from the stock of capital as new investment and retirement of old capital take place. The perpetual inventory method measures stocks at the end of a year equal to a weighted sum of all past investments, where the weights are the asset's efficiency relative to a new asset. A hyperbolic age-efficiency function is used to calculate the relative efficiency of an asset at different ages.

The hyperbolic age-efficiency function can be expressed as:

$$S_t = (L - t)/(L - (B)t)$$

where S_t = the relative efficiency of a t-year-old asset
L = the service life
t = the age of the asset
B = the parameter of efficiency decline

The parameter of efficiency decline is assumed to be 0.5 for equipment and 0.75 for structures. These parameters yield a function in which assets lose efficiency more slowly at first, then rapidly later in life.

Stocks of equipment, structures, inventories, and land are estimated separately. Individual price deflators for each asset category are constructed and used to convert the current-dollar investment to constant dollars. Industry-specific service lives are computed for each type of equipment asset for use in the perpetual inventory method.

Current-dollar values of inventory stocks are calculated for three separate categories of manufacturers' inventories: Finished goods, work in process, and materials and supplies. Inventory stocks for each year are calculated as the average of the end-of-year stocks in years t and t-1 to represent the average used during the year as a whole. This is also done with equipment, structures, and land. Current-dollar inventory values for the three categories of inventories are deflated with appropriate price indexes.

Land stocks are estimated as a function of the movement in constant-dollar gross structures stocks for the given industry.

Weights. The various equipment, structure, inventory, and land stock series in constant dollars are aggregated into one capital input measure using estimated rental prices to construct the weights. Rental prices are calculated for each asset as:

$$RP = \left[(P \times R) + (P \times D) - \left(P^t - P^{t-1}\right)\right] \times (1 - uz - k)/(1 - u)$$

where:

RP = the rental price
P = the deflator for the asset
R = the internal rate of return
D = the rate of depreciation for the asset

$P^t - P^{t-1}$ = the capital gain term for the asset

$1 - uz - k/(1 - u)$ reflects the effects of taxation where:

u = the corporate tax rate
z = the present value of $1 of depreciation deductions
k = the effective investment tax credit rate

This method of calculating rental prices is similar to that used in calculating multifactor productivity for major sectors of the economy except that no attempt is made to incorporate the effects of indirect business taxes, for which data are lacking at the industry level.

Rental prices are expressed in rates per constant dollar of productive capital stocks. Each rental price is multiplied by its constant-dollar capital stock to obtain current-dollar capital costs which are then converted to value shares for Tornqvist aggregation.

Sources. Industry capital indexes are developed from data published and maintained by the Bureau of the Census and the Bureau of Economic Analysis, U.S. Department of Commerce; and the Office of Employment Projections, Bureau of Labor Statistics. Price indexes are derived from producer price indexes developed by BLS.

Intermediate purchases

The index of intermediate purchases input is a Tornqvist aggregate of separate indexes of change in real materials, services, fuels, and electricity consumed by an industry. With the exception of electricity, for which both price and quantity data are available, the above indexes are calculated by dividing annual current-dollar values by appropriate price indexes to obtain constant-dollar annual estimates. Separate price deflators for materials and fuels for each industry are constructed using detailed price and value data for individual subcomponents of each group. The aggregate deflators are divided into the current-dollar values to derive constant-dollar estimates. The constant-dollar series for each component are indexed by dividing each year's estimate by the base-period aggregate.

Weights. The indexes of change in real materials, services, fuels, and electricity are weighted together with value share weights to derive an aggregate intermediate purchases index. These weights are derived by dividing the current-dollar values of each by the total combined value of intermediate purchases, and averaging these weights at times t and t-1.

Sources. Industry intermediate purchases indexes are developed from data published by the Bureau of the Census and the Bureau of Economic Analysis.

Weights for major input components

The indexes representing quantity change for each of the three major inputs are weighted together to compute the index of combined inputs. The relative weights for each year are derived from total costs for each input. All employee labor costs from Census data are used for the labor weight. The sum of current-dollar values for materials, services, fuels, and electricity constitute the weight for intermediate purchases. The weight for capital is derived by subtracting labor costs and an estimate of purchased services from Census value-added data. These cost shares are averaged at time t and t-1.

Presentation

BLS labor productivity and multifactor productivity indexes are published annually in the bulletin, *Productivity Measures for Selected Industries*. A limited amount of the most current data is provided in annual news releases. Technical notes describing the methodology used to develop the indexes are available on request.

Indexes of output per hour also are published in the *Statistical Abstract of the United States* and are available in the Bureau's LABSTAT database, and on BLS data diskettes or by accessing the data through the Internet, via anonymous FTP, at the address **stats.bls.gov** or from the BLS World Wide Web site: **http://stats.bls.gov**

Uses and Limitations

Measures of output per hour are useful for analyzing trends in labor costs, comparing productivity progress among countries, examining the effects of technological improvements, and analyzing related economic and industrial activities. Such analysis usually requires that indexes of output per hour be used in conjunction with other data. Specifically, related data on production and employment are useful in studying technological effects; to study trends in labor costs, data on earnings and other labor expenditures are necessary.

These productivity measures of output per hour are subject to certain qualifications. First, existing techniques may not fully take into account changes in the quality of goods and services produced. Second, although efforts have been made to maintain consistency of coverage between the output and labor input estimates, some statistical differences may remain. Third, estimates of nonproduction worker hours are subject to a wider margin of error than are the estimates of production worker hours because of the technique for estimating average employee hours of nonproduction workers. Errors in estimating hours of nonproduction workers, however, have a relatively insignificant effect on the estimates of hours for all employees. Fourth, industries in which all person hours are used as the denominator are subject to a wider margin of error because of the limited data available for unpaid family workers, the self-employed, and paid managers. Finally, year-to-year changes in output per hour are irregular, and, therefore, are not necessarily indicative of basic changes in long-term trends. Conversely, long-term trends are not necessarily applicable to any one year or to any period in the future. Because of these and other statistical limitations, these indexes cannot be considered precise measures; instead they should be interpreted as general indicators of movements of output per hour.

The output per hour measures relate output to only one input—labor time—as noted earlier. They reflect the joint effect of a number of influences including changes in technology, capital per worker, level of output, utilization of capacity, intermediate inputs per worker, layout and flow of material, skill and effort of the workforce, managerial skill, and labor-management relations. Indexes of multifactor productivity are subject to many of the same limitations previously mentioned with the exception of the effects of changes in the ratio of other factor inputs to labor. The construction of multifactor productivity measures permits an analysis of the effects of the changes in capital per hour and intermediate purchases per hour on output per hour. Labor productivity is related to multifactor productivity in the manner given by the following formula:

$$\ln\left(\frac{Q_t}{Q_{t-1}}\right)-\ln\left(\frac{L_t}{L_{t-1}}\right)=\ln\left(\frac{A_t}{A_{t-1}}\right)+w_k\left[\ln\left(\frac{K_t}{K_{t-1}}\right)-\ln\left(\frac{L_t}{L_{t-1}}\right)\right]+$$
$$w_{ip}\left[\ln\left(\frac{IP_t}{IP_{t-1}}\right)-\ln\left(\frac{L_t}{L_{t-1}}\right)\right]$$

The rate of change in labor productivity, on the left side of the equation above, is the difference between the rate of change in output and the rate of change in labor input. On the right side of the equation are the rates of change in multifactor productivity, and the rates of change in the weighted capital-labor ratio and the weighted intermediate-purchases-labor ratio. Thus, changes in labor productivity can be analyzed in terms of changes in multifactor productivity versus changes in the inputs of capital relative to labor and intermediate purchases relative to labor.

Technical References

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