Chapter 10. Productivity Measures: Business Sector and Major Subsectors

NOTE: This Handbook chapter does not reflect the most recent methodology in the Productivity programs. For up-to-date information on the labor productivity measures that BLS publishes for the major sectors of the U.S. economy, please visit http://www.bls.gov/lpc/lpcmethods.pdf. For the latest information on Multifactor Productivity, please visit http://www.bls.gov/mfp/mprtech.pdf.

Background

Indexes of labor productivity, multifactor productivity, and related measures for broad economic sectors and manufacturing industries are published by the Bureau of Labor Statistics. Quarterly and annual measures of output per hour, together with comparable measures of compensation per hour and unit labor costs, are maintained for business and nonfarm business from 1947 to the present. Similar measures are also available for manufacturing (total, durable, and nondurable sectors) and for nonfinancial corporations.

The multifactor productivity indexes for major sectors measure the value-added output per combined unit of labor and capital input in private business and private nonfarm business. Multifactor productivity indexes for aggregate manufacturing and for 20 manufacturing industries provide measures of sector output per combined unit of capital (K), labor (L), energy (E), materials (M), and purchased business services (S) inputs—KLEMS inputs.

Table 1 summarizes the availability of productivity measures for major sectors of the U.S. economy.

Table 1. Availability of productivity measures for major sectors and subsectors of the economy

Productivity measure	Input(s)	Index available
Labor productivity:[1]		
Business[1]	Labor	Quarterly
Nonfarm business	Labor	Quarterly
Nonfinancial corporations	Labor	Quarterly
Manufacturing, total	Labor	Quarterly
Durable	Labor	Quarterly
Nondurable	Labor	Quarterly
Multifactor productivity:		
Private business	Labor, capital	Annually
Private nonfarm business	Labor, capital	Annually
KLEMS[2] multifactor productivity:		
Manufacturing and 20 2-digit SIC manufacturing industries	Labor, capital energy, materials, services	Annually

[1] Includes government enterprises; multifactor productivity measures exclude such enterprises.

[2] Capital (K), labor (L), energy (E), materials (M), and purchased business services (S) inputs.

IN THIS CHAPTER

Description of Measures

BLS publishes three sets of productivity measures for the major sectors and subsectors of the U.S. economy, each using a distinct methodology. One measure includes labor productivity for the major sectors of business, nonfarm business, and nonfinancial corporations and for the subsectors of total, durable, and nondurable manufacturing. The second set includes multifactor productivity for major sectors; and the third measures multifactor productivity for total manufacturing and 20 2-digit Standard Industrial Classification manufacturing industries. Each set of measures involves a comparison of output and input measures.

The traditional measure of labor productivity—output per hour—was first published in 1959, and represents the culmination of a long series of developments in productivity

measurement in the Bureau.[1] Output, measured net of price change and inter-industry transactions[2], is compared to labor input, measured as hours at work in the corresponding sector. These measures are prepared for the business sector, the nonfarm business sector, nonfinancial corporations, and manufacturing, along with subsectors of durable and nondurable goods manufacturing. These measures are available quarterly and are updated and revised eight times a year.

The second set of measures covers multifactor productivity for major U.S. sectors.[3] In these measures, output is again measured net of price changes and inter-industry transactions, but the input measure is an aggregate of hours at work and capital service flows. These measures have been developed in recognition of the role capital growth plays in output growth. They are updated annually.

Comparisons of output with a broader set of inputs constitute the third set of measures.[4] Because the scope of industries within manufacturing is narrower than that of the nonfarm business sector, output in manufacturing industries includes shipments to both other producers and final consumers.[5] Consistent with such an output concept is an input measure which includes intermediate inputs. Accordingly, input includes labor and capital, and also energy, nonenergy materials, and purchased business services. These measures are available for a comprehensive set of 20 manufacturing industries (corresponding to the 2-digit Standard Industrial Classification (SIC) level) as well as for total manufacturing. As the focus narrows to more specific industries, intermediate inputs take on an increasingly important role in productivity measurement and analysis. This set of measures consists of annual data and is updated approximately every 2 years.

[1] *Trends in Output per Man-Hour in the Private Economy, 1909-58*, Bulletin 1249 (Bureau of Labor Statistics, 1959).

[2] The output measures represent deliveries of final goods and services by the sector to domestic households, investment, government and nonprofit institutions, and net exports to other countries. These measures are gross in the sense that neither capital consumption allowances nor purchases of capital goods are deducted, but they are net in the sense that inter-industry transactions in intermediate materials and services are excluded from output. These transactions are excluded to avoid double counting. For example, the output of the steel industry is excluded to the extent that it is incorporated in final products such as automobiles.

[3] *Trends in Multifactor Productivity, 1948-81*, Bulletin 2178 (Bureau of Labor Statistics, 1983).

[4] These measures were first introduced in William Gullickson and Michael J. Harper, "Multifactor Productivity in 20 U.S. Manufacturing Industries, 1949-83," *Monthly Labor Review*, October 1987, pp. 18-28. A similar measure for utility services industries is in John L. Glaser, "Multifactor Productivity in the Utility Services Industries," *Monthly Labor Review*, May 1993, pp. 34-49.

[5] In the more aggregate sectors, such as business and nonfarm business, the delivery of goods to final users closely corresponds to value added or gross product originating (GPO). In less aggregate economic sectors, such as manufacturing, where inter-industry transaction represent a smaller proportion of goods and services produced, deliveries include output which is not part of final demand and more closely approximates a gross output measure.

Data Sources and Estimating Procedures

Output per hour measures

Output. Real gross domestic product in the business and nonfarm business sectors is the basis of the output components of the major sector labor productivity and multifactor productivity measures. These output components are based on and are consistent with the National Income and Product Accounts (NIPA), including the gross domestic product (GDP) measure, prepared by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce[6].

Real business sector output is an annual-weighted (Fisher-Ideal) index. It is constructed from the gross domestic product (GDP) excluding the following outputs: General government, nonprofit institutions, paid employees of private households, and the rental value of owner-occupied dwellings. These same exclusions are made when calculating current dollar output for the sector. The business sector thereby excludes many activities where it is difficult to draw inferences on productivity from NIPA output measures. Such inferences would be questionable mainly because the output measures are based largely on incomes of input factors. The farm sector, which is subject to unique external forces, also is excluded to yield the nonfarm business sector, the principal focus of many productivity studies. Nonfinancial corporate output is similar to that of the business sector but also excludes unincorporated businesses and those corporations which are depository institutions, nondepository institutions, security and commodity brokers, insurance carriers, regulated investment offices, small business offices, and real estate investment trusts.

Annual manufacturing indexes for both the quarterly labor productivity and KLEMS multifactor productivity measures are constructed by deflating the current-dollar industry value of production provided by the U.S. Bureau of the Census with data from BEA. These deflators are constructed by BEA by combining data from the BLS producer price program and other sources. The industry shipments are aggregated using annual weights, and intrasector transactions

[6] A detailed description of the methods and procedures for estimating GNP and GDP in current and constant dollars is given in Carol S. Carson, "GNP: An Overview of Sources Data and Estimating Methods," *Survey of Current Business*, July 1987, pp. 103-26. Also see Methodology Paper No. 1 "Introduction to National Income Accounting" (Bureau of Economic Analysis, 1985). The current chain-type annual-weighted quantity measures are discussed in Allan H. Young, "Alternative Measures of Change in Real Output and Prices," *Survey of Current Business*, April 1992, pp. 32-48. These official introduction of these measures into the National Accounts is discussed in J. Steven Landefeld and Robert P. Parker, "Preview of the Comprehensive Revision of the National Income and Product Accounts: BEA's New Featured Measures of Output and Prices," *Survey of Current Business*, July, 1995, pp. 31-38. Derivation of business sector output is discussed also in Jerome A. Mark, "Measuring Single-Factor and Multifactor Productivity, *Monthly Labor Review*, December 1986, pp. 3-11.

are removed[7]. Quarterly manufacturing output measures are based on the index of industrial production prepared monthly by the Board of Governors of the Federal Reserve System, adjusted to be consistent with the annual indexes of manufacturing sector output prepared by BLS.

Labor input. The primary source of hours and employment data is the BLS Current Employment Statistics (CES) program, which provides monthly survey data on total employment and employment and average weekly hours of production and nonsupervisory workers in nonagricultural establishments. Jobs rather than persons are counted, so that multiple jobholders are counted more than once.

The CES data are based on payroll records from a sample of establishments in which the probability of sample selection is related to the establishment size. Data on employment, hours, and earnings are collected monthly; the reference period for these data is the payroll period including the 12th of the month. (The CES methods are described in chapter 2.) Establishment data are published monthly in *Employment and Earnings.*

Because CES data include only nonfarm wage and salary workers, data from the Current Population Survey (CPS) are used for farm employment. In the nonfarm sector, the CPS is also used for proprietors and unpaid family workers. Government enterprise hours are developed from the National Income and Product Accounts estimates of employment and CPS data on average weekly hours.

Separate estimates for employment and hours paid are developed for each major sector, converted to an hours-at-work basis. The labor input of employees of nonprofit corporations are estimated based on data from the Commerce Department's Bureau of the Census and Bureau of Economic Analysis and subtracted from the totals for each major sector. Hours of labor input are treated as homogeneous units; no distinction is made among workers with different skill levels or wages.

For nonmanufacturing sectors, employment and average weekly hours are computed from the CES, CPS, and NIPA sources. Although CES data on average weekly hours refer only to nonsupervisory workers, it is assumed for the computation of hours that the length of the workweek in each nonmanufacturing industry is the same for all wage and salary workers.

In manufacturing, separate measures for production and nonproduction workers' hours are derived and aggregated to the manufacturing total. Employment and average weekly hours for production workers and employment for nonproduction workers are taken directly from CES data. Average weekly hours for nonproduction workers were developed from BLS studies of wages and supplements in manufacturing which provide data on the regularly scheduled workweek of white-collar employees.

In the CES, weekly hours are measured as hours paid rather than hours at work. The Hours at Work Survey is used to convert the hours paid of nonagricultural production and nonsupervisory employees to an hours-at-work basis.[8] Hours at work exclude all forms of paid leave, but include paid time to travel between job sites, coffee breaks, and machine downtime. This survey of about 5,500 establishments has collected quarterly and annual ratios of hours at work to hours paid since 1981.[9] (See BLS form 2000P1 at end of this chapter for a sample data collection form for manufacturing industries. Form 2000N1 is a virtually identical form for nonmanufacturing industries and is not reproduced.) Ratios are developed for each 2-digit SIC industry within manufacturing and for each 1-digit SIC industry outside of manufacturing.

Unpublished data and one-time surveys have been used to extend the annual ratios back to 1947 as well as develop ratios for nonproduction and supervisory workers.[10] The quarterly ratios are not currently used in the quarterly measures of labor input. Instead, a quadratic minimization formula devised by Frank Denton is used to generate quarterly ratios.[11]

The resultant quarterly measures are used to convert the paid hours of nonfarm employees to an hours-at-work basis. The estimates of hours of farm workers, proprietors, unpaid family workers, employees of government enterprises, and paid employees of private households are collected on an hours-at-work basis. These hours are only adjusted to include information on those persons who are employed but not at work during the survey week.

Compensation and labor costs. BEA develops employee compensation data as part of the national income accounts. These quarterly data include direct payments to labor—wages and salaries (including executive compensation), commissions, tips, bonuses, and payments in kind representing income to the recipients—and supplements to these direct payments. Supplements consist of vacation and holiday pay, all

[7] A discussion of manufacturing output measures is given in William Gullickson, "Measurement of productivity growth in U.S. manufacturing," *Monthly Labor Review*, July 1995, pp. 13-28.

[8] Kent Kunze, "A New BLS Survey Measures the Ratio of Hours Worked to Hours Paid," *Monthly Labor Review*, June 1984, pp. 3-7.

[9] The sample design and universe of establishments for the Hours at Work survey are essentially the same as those used in the Current Establishments Statistics program. The response rate has ranged from 70 to more than 80 percent including responses obtained through computer assisted telephone interviews.

[10] A description of the hours at work ratios for the period 1948 through 1988 can be found in Mary Jablonski, Kent Kunze, and Phyllis Flohr Otto, "Hours at Work: A New Base for Productivity Statistics," *Monthly Labor Review*, February 1990, pp. 17-24.

[11] See Frank T. Denton, "Adjustment of Monthly and Quarterly Series to Annual Totals: An Approach Based on Quadratic Minimization," *Journal of the American Statistical Association*, March 1971, pp. 99-102. This method is also used to produce quarterly ratios prior to 1981.

other types of paid leave, employer contributions to funds for social insurance, private pension and health and welfare plans, compensation for injuries, etc.

The compensation measures taken from establishment payrolls refer exclusively to wage and salary workers. Labor cost would be seriously understated by this measure of employee compensation alone in sectors such as farm and retail trade, where hours at work by proprietors represent a substantial portion of total labor input. BLS, therefore, imputes a compensation cost for labor services of proprietors and includes the hours of unpaid family workers in the hours of all employees engaged in a sector. Labor compensation per hour for proprietors is assumed to be the same as that of the average employee in that sector for measures found in the BLS news release, "Productivity and Costs."

Multifactor productivity measures

Major sectors. The multifactor productivity indexes for major sectors measure output per combined unit of labor and capital input in private business and private nonfarm business. The output measures for private business and private nonfarm business are similar to the Fisher-Ideal indexes of output for business and nonfarm business except that output of government enterprises is omitted. Estimates of the appropriate weights for labor and capital in government enterprises cannot be made because subsidies account for a substantial portion of capital income.

Labor input for the multifactor productivity measures in these sectors begins with hours at work data similar to the hours in the quarterly labor productivity program with two principle differences. First, the hours of employees of government enterprises are excluded. Second, the hours at work for each of 1,008 types of workers classified by their educational attainment, work experience and gender are aggregated using an annually chained (Tornqvist) index. The growth rate of the aggregate is therefore a weighted average of the growth rates of each type of worker where the weight assigned to a type of worker is its share of total labor compensation. The resulting aggregate measure of labor input accounts for both the increase in raw hours at work and changes in the skill composition (as measured by education and work experience) of the work force.[12]

Capital inputs for the multifactor productivity measures are computed in accordance with a service flow concept for physical capital assets—equipment, structures, inventories, and land. Capital inputs for major sectors are determined in three main steps: 1) A very detailed array of capital stocks is developed for various asset types in various industries; 2) asset-type capital stocks are aggregated for each industry to measure capital input for the industry; and 3) industry capital inputs are aggregated to measure sectoral level capital input.

The asset detail consists of 28 types of equipment, 22 types of nonresidential structures, 9 types of residential structures (owner-occupied housing is excluded), 3 types of inventories (by stage of processing), and land. BLS measures of capital stocks for equipment and structures are prepared using NIPA data on real gross investment. Real stocks are constructed as vintage aggregates of historical investments (in real terms) in accordance with an "efficiency" or service flow concept (as distinct from a price or value concept). The efficiency of each asset is assumed to deteriorate only gradually during the early years of an asset's service life and then more quickly later in its life. These "age/efficiency" schedules are based, to the extent possible, on empirical evidence of capital deterioration. Inventory stocks are developed using data from the NIPA. Farm land input is based on data from the Economic Research Service of the U.S. Department of Agriculture. A benchmark for nonfarm land is estimated by applying a land-structure ratio based on unpublished estimates by the Bureau of the Census to BLS estimates of the value of stuctures. This benchmark is extrapolated using gross stocks of structures calculated from Bureau of Economic Analysis investment data. The resulting nonfarm land data series is allocated to industries based on Internal Revenue Service data on book values of land.[13]

For each industry (the BLS procedures are applied to 57 industries in the private business sector corresponding, approximately, to the 2-digit SIC level), these measures of capital stocks are aggregated using a Tornqvist chain index procedure (described below). The weight for each asset type is based on the share of property income estimated to be accruing to that asset type in each industry averaged over 2 years. Property income in each industry is allocated to asset types by employing estimates of the "implicit rental prices" of each asset type.[14] The implicit rental price concept is based on the neoclassical theory of the firm and provides a framework for deriving weights for asset-type capital stocks. Because some asset types tend to deteriorate much more quickly than

[12] See *Labor Composition and US Productivity Growth, 1948-90* for a complete description of Tornqvist aggregation of hours.

[13] These methods are described in detail in *Trends in Multifactor Productivity, 1948-81*, appendix C.

[14] The rental price formula and related methodology and data sources are described in *Trends in Multifactor Productivity, 1948-81*, appendix C. The rental price formulas described in this publication have been modified to eliminate large fluctuations due to inflation in new goods prices. Research on this issue is reported by Michael J. Harper, Ernst R. Berndt and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in Dale W. Jorgenson and Ralph Landau, *Technology and Capital Formation*, 1989, MIT Press, pp. 331-37.

others and because of tax rules specific to asset types, the real economic cost of employing a dollar's worth of stock varies substantially by asset type.

At the sector level, aggregate capital input is obtained by further chained (Tornqvist) aggregation of each industry's capital input using each industry's two-period average share of total capital income as weights.

Once the sector's capital input is measured, total input is computed by aggregating capital and labor. For each input, the weight is the input's share of total costs and is derived from NIPA data on the components of nominal gross product originating (GPO) by industry. At both the sector and the industry levels, labor costs are measured as compensation to employees (wages, salaries, and supplements) plus a portion of noncorporate income.[15] Most other components of nominal GPO are assigned to capital.[16] The exception is those indirect taxes which are not assigned either to capital or labor (notably sales and excise taxes). Thus total cost is less than GPO by an amount equal to these taxes. Labor and capital shares *in total cost* are computed and then used in the aforementioned aggregation of capital and labor.[17] Finally, major sector multifactor productivity indexes are calculated as the ratio of output to input.

Manufacturing industries. Multifactor productivity indexes for aggregate manufacturing and for 20 manufacturing industries also measure output per unit of input. In this case, input is a weighted aggregate of capital, labor, energy, nonenergy materials, and purchased business services inputs.[18]

For these multifactor productivity manufacturing measures, output is the deflated value of production, adjusted for inventory change, shipped to purchasers outside of the industry and not just final users. Hence, it differs from the output measures used for the major sector multifactor productivity indexes. Capital is measured as it is for the major sector multifactor productivity indexes; rental prices of capital are computed for each industry. However, labor is measured as a direct summation of hours at work rather than as the Tornqvist index method used in the major sector multifactor productivity measures.

The inclusion in the industry multifactor productivity measures of all intermediate inputs—energy, nonenergy materials, and purchased business services—is consistent with the use of total value of production as the output measure. Energy input is constructed using data on the price and quantity of fuels purchased for use as heat or power. Nonenergy materials input includes all commodity inputs exclusive of fuels but inclusive of fuel-type inputs used as raw materials in manufacturing. The measures of purchased business services are constructed using price and value data on services purchased by manufacturing industries from service industries. Data sources used in constructing these three inputs include input-output tables, surveys of establishments in manufacturing and other industries, and price indexes.

Total input is computed from components as a Tornqvist chain index number series. The weight for each input is its share in total input cost. The multifactor productivity industry measures are available for 1949 to the present.

Analysis and Presentation

Indexes of labor productivity show changes in the ratio of output to hours of labor input. Similarly, indexes of multifactor productivity show changes in the ratio of output to combined inputs. However, these indexes should not be interpreted as presenting the contribution of the particular input, or combination of inputs, to production. Rather, changes over time in the output, labor input, or combined input measures underlying these productivity indexes may reflect the influence of other factors including variations in the characteristics and efforts of the work-force, changes in the managerial skill, changes in the organization of production, changes in the allocation of resources between sectors, the direct and indirect effects of R&D, and new technology.

Compensation and labor costs

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

[15] Noncorporate income is allocated to labor and capital costs in each year using the following assumption: Initially self-employed persons are assumed to receive the same hourly compensation as employees and the rate of return to non-corporate capital is assumed to be the same as in the corporate sector. Based on these assumption, the resultant income of proprietors is adjusted to match proprietors income reported in the GPO data by scaling proportionately the hourly compensation of the self-employed and the noncorporate rate of return.. This treats any apparent excess or deficiency in noncorporate income neutrally with respect to labor and capital.

[16] Capital costs are the sum of 1) the balance of noncorporate income, 2) corporate profits, 3) net interest, 4) rental income, 5) adjusted capital consumption allowance, 6) inventory valuation adjustments, and 7) portions of indirect taxes assumed to be associated with capital (notably motor vehicle and property taxes), 8) the sum of business transfers and government subsidies.

[17] Excluding these indirect business taxes from the calculation of factor shares has the effect of assuming the incidence of these taxes are neutral with respect to capital and labor income.

[18] An explanation of the methods and some results are presented in William Gullickson and Michael J. Harper, "Multifactor Productivity in U.S. Manufacturing, 1949-83," *Monthly Labor Review*, October 1987, pp. 18-28.

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

Unit labor and nonlabor costs

The Bureau also prepares data on labor and nonlabor costs per unit of output for the business sector and its major components. Unit labor costs relate hourly compensation of all persons to output per hour and are defined as compensation per unit of real output. Nonlabor *payments* are the excess of current-dollar output in an economic sector over corresponding labor compensation, and include nonlabor *costs* as well as corporate profits and the profit-type income of proprietors. Nonlabor costs include interest, depreciation, rent, and indirect business taxes.

In aggregate sectors, productivity changes through time reflect movements within the various component industries as well as shifts in the relative importance of each of the industries. For example, changes in labor productivity and multifactor productivity are influenced by the relative shift of inputs (labor and capital) from low- to high-productivity industries and by productivity changes in the component subsectors.[19]

Short-term movements in productivity and unit labor costs often result from cyclical variation in output, as noted below, and may also reflect unusual events such as drought. These short-term movements are sometimes substantially greater or smaller than long-term averages of productivity and cost movements. For example, productivity growth for 1 or 2 years can be substantially greater than the average for the business cycle that includes these years.

Availability of results

Indexes of output per hour, compensation per hour, and related cost data are published twice each quarter in the BLS news release, "Productivity and Costs." In addition, quarterly and annual analyses are published from time to time in the *Monthly Labor Review.* Historical indexes of these and related data are available on request, as are detailed descriptions of data sources and computational procedures.

Multifactor productivity measures are announced each year in the news release, "Multifactor Productivity Trends." Included are annual indexes of multifactor productivity, capital inputs, and related measures for private business, private nonfarm business, and manufacturing.

[19] The farm-nonfarm shift is examined in some detail by J.R. Norsworthy and L.J. Fulco in "Productivity and Costs in the Private Economy," *Monthly Labor Review*, June 1974, pp. 3-9.

Indexes of productivity and related cost data are available monthly in *Monthly Labor Review*, and can be accessed through the BLS homepage at **http://www.bls.gov** on the Internet. These sources also include data from the multifactor and KLEMS productivity measures.

Information on trends in KLEMS productivity in manufacturing and the ratio of hours at work to hours paid is available on request from the Bureau.

Calculation Procedures

Labor productivity

Labor productivity, or output per hour, is computed as:

Labor productivity = (Output index) / (Hours of labor input)

or

$$P = O / H$$

The computation of labor compensation per hour parallels the computation of output per hour. Unit labor costs (ULC) are computed as labor compensation (C) per unit of output, but are often represented as:

$$ULC = (C / H) / (O / H)$$

This form highlights the relationships between unit labor costs, hourly compensation, and labor productivity.

Real compensation per hour (RC) is computed as hourly compensation deflated by the seasonally adjusted Consumer Price Index for All Urban Consumers (CPI-U):

$$RC = (C / H) / CPI\text{-}U$$

Unit nonlabor payments (UNLP) include all nonlabor components of gross product originating in a given sector—depreciation, rent, interest, and indirect business taxes as well as profits and profit-type income—whereas unit nonlabor cost (UNLC) excludes profit. These measures are computed as:

$$UNLP = (CU - C) / O$$

and

$$UNLC = (CU - C - PR) / O$$

where:

CU is current-dollar output,
C is current-dollar compensation,
O is the output index, and
PR is current-dollar profits.

Labor's share in current dollar output in a given sector is simply the ratio of labor compensation paid in that sector to current dollar output:

$LS = C / CU$

and, analogously, the nonlabor or capital share is defined as:

$NLS = (CU - C) / CU = 1 - LS.$

Most of the measures noted above are presented quarterly in index form. Indexes are computed from basic data or analytic ratios by dividing the series by its own base year annual value (presently 1992) and multiplying by 100. In addition, quarterly percent changes at a compound annual rate and percent changes from the same quarter in the previous year are computed:[20]

$Q_t = 100 (V_t / V_{t-1})^4 - 100$
$Y_t = 100 (V_t / V_{t-4}) - 100,$
where:

t	is a time subscript denoting the quarter,
V	is a series described above,
Q_t	is the quarterly percentage change in series V from quarter t-1 to quarter t, measured at a compound annual rate,
Y_t	is the percentage change in series V from quarter t-4 (the same quarter 1 year before) to quarter t.

Indexes and percent changes are published to one decimal point. In order not to lose precision, all computations are made from the underlying measures themselves rather than from the published indexes.

Multifactor productivity

BLS aggregates inputs for its multifactor productivity measures using a Tornqvist chain index. Some of the basic properties of this index are: It is calculated as a weighted average of growth rates of the components; the weights are allowed to vary for each time period; and the weights are defined as the mean of the relative compensation shares of the components in two adjacent years. Hence, the growth rate of the index (I) for major sectors is the proportional change over time (the triangle (delta) refers to discrete change with respect to time), such that:

$$\%\Delta I = \exp(\Delta \ln I) = \exp\{1/2 * [s_k(t) + s_k(t-1)] \Delta \ln K + 1/2 * [s_l(t) + s_l(t-1)] \Delta \ln L\}$$

where $s_l(t)$ = labor costs(t)/total costs(t)
and $s_k(t)$ = capital costs(t) / total costs(t)

Similarly, both capital, K, and labor, L are Tornqvist indexes. Each is a weighted average of the growth rates of detailed types of capital, k_i, and labor inputs, l_i, respectively.

$$\%\Delta K = \exp(\Delta \ln K) = \exp\{\Sigma_i\ 1/2 * [s_{ki}(t) + s_{ki}(t-1)] \Delta \ln k_i\}$$

where $s_{ki}(t) = c_{ki}(t) * k_i(t)$/ total capital costs
and where $c_{ki}(t)$ is the rental price for capital asset k_i.

$$\%\Delta L = \exp(\Delta \ln L) = \exp\{\Sigma_i\ 1/2 * [s_{li}(t) + s_{li}(t-1)] \Delta \ln l_i\}$$

where $s_{li}(t) = w_{li}(t) * l_i(t)$/ total capital costs
and $w_{li}(t)$ is the hourly compensation for worker group l_i.

Changes in the index of labor composition, LC, are defined as the difference between changes in the aggregate labor input index, L, and the simple sum of the hours of all persons, H.

$$\%\Delta LC = \exp(\Delta \ln LC) = \exp(\Delta \ln L - \Delta \ln H)$$

The Tornqvist index for major sector multifactor productivity growth, A, is:

$$\%\Delta A = \exp(\Delta \ln A) = \exp(\Delta \ln Q - \Delta \ln I)$$

where Q is the Fisher-Ideal index of sector output as measured by BLS.

For manufacturing and the 20 industries which comprise manufacturing, aggregate input has a conceptually similar definition except that there are 5 inputs rather than just the 2 used in the major sector measures.

$$\%\Delta I = \exp(\Delta \ln I) = \exp\{1/2 * [sk(t) + sk(t-1)) \Delta \ln K + 1/2 * [sl(t) + sl(t-1)] \Delta \ln L + 1/2 * [s_e(t) + s_e(t-1)] \Delta \ln E + 1/2 * [s_m(t) + s_m(t-1)] \Delta \ln M + 1/2 * [s_s(t) + s_s(t-1)] \Delta \ln S\}$$

[20] The estimation of quarterly (or subannual) changes at compound annual rates as the differences between movements in the underlying series involves approximations. For changes in the neighborhood of 1 or 2 percent, these approximations are good; however, the inexactness of these approximations is amplified by relatively large changes in the economic measures such as those experienced during periods of inflation, sharp recession, and rapid recovery.

Since most of the productivity and costs measures are reported as percentages to one decimal place, e.g., 2.6 percent, questions sometimes arise because the greater precision carried in the automated computation results in differences in related measures in the final decimal place.

where L = total hours at work

$s_l(t)$ = labor costs(t)/total costs(t)

$s_k(t)$ = capital costs(t) / total costs(t)

$s_e(t)$ = energy costs(t)/total costs(t)

$s_m(t)$ = materials costs(t) / total costs(t)

$s_s(t)$ = purchased business services costs(t) / total costs(t)

and total costs are the current dollar value of shipments adjusted for inventory change.

Using this definition for aggregate input, multifactor productivity for manufacturing or any of the 20 industries which comprise manufacturing is identically defined as above.

$$\%\Delta A = \exp(\Delta \ln A) = \exp(\Delta \ln Q - \Delta \ln I)$$

where Q is a Tornqvist output index developed by BLS.

Uses and Limitations

Measures of output per hour (labor productivity), output per unit of capital (capital productivity), and output per combined unit of multifactor input (multifactor productivity) and related measures of costs are designed for use in economic analysis and public and private policy planning. The data are used in forecasting and analysis of prices, wages, and technological change.

The labor productivity, multifactor productivity, and related cost measures are useful in investigating the relationships between productivity, wages, prices, profits, and costs of production. As noted above, gross domestic product represents the sum of all production costs: labor compensation, profits, depreciation, interest, rent, indirect business taxes, and other minor items. Unit labor costs, or compensation per unit of output, represent a major portion of total unit costs and reflect the combined effect of changes in output per hour and compensation per hour; thus, an increase in compensation per hour tends to increase unit labor costs while an increase in output per hour tends to reduce them, other things being equal. Therefore, through its impact on unit labor costs, output per hour is an important element in the wage-price relationship because it is an indicator of the extent to which compensation gains can occur without putting pressure on prices or reducing payments to other input factors.

Certain characteristics of the productivity and related cost data should be recognized in order to apply them appropriately to specific situations. First, the data for aggregate sectors reflect changes within various constituent industries as well as shifts in the relative importance of these industries: a portion of labor productivity growth from 1947 to the mid-1960s is attributable to the shift of workers from farm to nonfarm occupations. Second, the relationships among variables are often difficult to identify over short time periods. Third, data and other resources available for their preparation somewhat limit the productivity, output, compensation, and employment measures which can be constructed. In several sectors where output is difficult to define in a satisfactory way, productivity measures are correspondingly weak. Examples are the construction industry and the financial services sector, where output is an imputed value of labor and other inputs. The productivity and costs measures for these sectors should be interpreted with caution.

Technical References

Bureau of Labor Statistics

Labor Composition and U.S. Productivity Growth, 1948-90, Bulletin 2426, December 1993.

Changes in the educational attainment and experience of the work force are measured and their impact on multifactor productivity are measured.

Productivity: A Selected Annotated Bibliography 1983-1987, Bulletin 2360, 1990.

Recent references concerning productivity and productivity measurement. Each reference includes a brief annotation.

The Impact of Research and Development of Productivity Growth, Bulletin 2331, 1989.

Presents annual measures of the stock of research and development and its contribution to productivity growth in the nonfarm business sector. The data cover 1948 to 1987.

Trends in Multifactor Productivity, 1948-81, Bulletin 2178, 1983.

Presents BLS annual indexes of multifactor productivity for private business, private nonfarm business, and manufacturing for the period 1948 through 1981. Also presents BLS annual measures of output per unit of capital services input for the three sectors.

Dean, Edwin; Harper, Michael; and Otto, Phyllis Flohr, "Improvements to the quarterly productivity measures," *Monthly Labor Review*, October 1995.

Summarizes the impact of switching from fixed-weighted to annual-weighted output on the labor productivity measures.

Gullickson, William, "Measurement of productivity growth in U.S. manufacturing," *Monthly Labor Review*, July 1995.

Updates multifactor (KLEMS) productivity measures for each 2-digit SIC. Contains a discussion of alternative manufacturing output measures and their use in productivity measurement.

Jablonski, Mary; Kunze, Kent; and Otto, Phyllis Flohr, "Hours at Work: A New Base for BLS Productivity Statistics," *Monthly Labor Review*, February 1990.

A description of the methodology used to develop measures of the ratio of hours at work to hours paid for the period 1948 to the present by linking the Hours at Work survey to early periodic surveys and unpublished data sources.

Harper, Michael J.; Berndt, Ernst R.; and Wood, David O. "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in D.W. Jorgenson and R. London, *Technology and Capital Formation*, MIT Press, 1989.

Examines the theoretical rationale for and empirical implementation of rental price formulas for use in weighting capital assets for multifactor productivity measurement.

Hulten, Charles R.; Robertson, James W.; and Wykoff, Frank C. "Energy, Obsolescence, and the Productivity Slowdown," in D.W. Jorgenson and R. London, *Technology and Capital Formation*, MIT Press, 1989.

An empirical examination of the hypothesis that high energy prices contributed to the post-1973 productivity slowdown by inducing capital obsolescence.

Dean, Edwin; Kunze, Kent; and Rosenblum, Larry. "Productivity Change and the Measurement of Heterogeneous Labor Inputs," prepared for Conference on New Measurement Procedures for U.S. Agricultural Productivity, March 1989.

Changes in the education and experience distribution of the workforce (based on a new model) show a modest contribution to productivity growth (0.2 percent annually) and very little explanation of the productivity slowdown.

Harper, Michael J. and Gullickson, William. "Cost Function Models and Accounting for Growth in U.S. Manufacturing, 1949-86," prepared for the National Bureau of Economic Research Summer Institute, 1989.

The effects of factor substitution induced by relative price changes on labor productivity are assessed using an econometric cost function model.

Powers, Susan G. "The Role of Capital Discards in Multifactor Productivity Measurement," *Monthly Labor Review*, June 1988.

Current measures of capital stocks do not reflect a firm's choice of when to discard capital. Capital stocks based on variations in capital discards over the business cycle are constructed. It is shown that multifactor productivity measures using these stocks do not significantly differ from the current productivity measures.

Dean, Edwin R. and Kunze, Kent. "United States Multifactor Productivity Growth, 1948-86," *Monthly Labor Review*, May 1988.

Presents growth rates of multifactor productivity for the periods 1948-73, 1973-79, and 1979-86 for private business, nonfarm business, and manufacturing. Analyzes trends in multifactor measures and describes data revisions and methodological improvements that have been incorporated into these measures.

Gillickson, William and Harper, Michael J. "Multifactor Productivity in 20 U.S. Manufacturing Industries, 1949-83," *Monthly Labor Review*, October 1987.

Presents multifactor productivity measures for 20 manufacturing industries and for total manufacturing, based on annual measures of output and inputs of capital, labor, energy, materials, and purchased business services. Analyzes multifactor growth rates in manufacturing industries.

Fulco, L. J. "U.S. Productivity Growth Since 1982: The Post-Recession Experience," *Monthly Labor Review*, December 1986.

A review of developments in major sectors of the economy focusing on the first 14 quarters of the recovery phase of the business cycle. Contrasts experience during the recovery which began in the fourth quarter of 1982 with all previous post-World War II cycles.

Mark, Jerome A. "Problems Encountered in Measuring Single-Factor and Multifactor Productivity," *Monthly Labor Review*, December 1986.

Development of new data sources, better use of existing sources, and broader coverage are some of the ways in which BLS has improved its productivity measures; progress has been made, but inadequacies remain.

Sveikauskas, Leo. "The Contribution of R&D to Productivity Growth," *Monthly Labor Review*, March 1986.

Results of a BLS study suggest that the direct contribution of research and development to post-War productivity growth was between 0.1 and 0.2 percent annually in the nonfarm business sector; R&D had no substantial effect on the post-1973 productivity slowdown.

Kunze, Kent. "A New BLS Survey Measures the Ratio of Hours Worked to Hours Paid," *Monthly Labor Review*, June 1984.

Hours at work accounted for about 93 percent of hours paid for production and nonsupervisory workers in 1982, according to an annual survey which includes only the time required to be on the job site, thereby excluding paid holidays, sick leave, and vacations.

Mark, Jerome A. and Waldorf, William H. "Multifactor Productivity: A New BLS Measure," *Monthly Labor Review*, December 1983.

Annual indexes for private business show that advances in multifactor productivity account for most of the growth of output per hour of all persons during 1948-81.

Harper, Michael J. "The Measurement of Productive Capital Stock, Capital Wealth and Capital Services," BLS Working Paper No. 128, 1982.

Analysis of the computation of capital depreciation for productivity measurement.

Other publications

Baily, Martin Neil and Gordon, Robert J. "Measurement Issues, the Productivity Slowdown, and the Explosion of Computer Power," *Brookings Papers on Economic Activity*. Washington, DC, The Brookings Institution, 1989.

Jorgenson, Dale; Gollop, Frank; and Fraumeni, Barbara. *Productivity and U.S. Economic Growth*, Cambridge, MA, The Harvard University Press, 1987.

Denison, Edward F. *Trends in American Economic Growth, 1929-1982*. The Brookings Institution, Washington, DC, 1985.

Caves, Douglas W.; Christensen, Laurits R.; and Diewert, W. Erwin. "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity," *Econometrica*, Vol. 50, No. 6, 1983, pp. 1393-1414.

Kendrick, John W. and Vaccara, Beatrice N., editors. *New Developments in Productivity Measurement and Analysis*. Chicago, The University of Chicago Press, 1980.

Usher, Dan, ed. *The Measurement of Capital*. Chicago, The University of Chicago Press, 1980.

National Research Council's Panel to Review Productivity Statistics. *Measurement and Interpretation of Productivity*. Washington, DC, The National Academy of Sciences, 1979.

Christensen, Laurits and Jorgenson, Dale. "The Measurement of U.S. Real Capital Input, 1929-67," *Review of Income and Wealth*, December 1969.