Productivity Measures: Business Sector and Major Subsectors

Major Sector Productivity (MSP) is a Bureau of Labor Statistics program that produces measures of productivity for six U.S. major industry sectors in the United States: business, nonfarm business, nonfinancial corporations, total manufacturing, durable goods manufacturing, and nondurable goods manufacturing. BLS compiles and analyzes a wide array of data produced by government statistical agencies and nongovernmental organizations to measure productivity.

Quick Facts: Productivity Measures: Business Sector and Major Subsectors	
Subject areas	Productivity
Key measures	Labor productivity Major sector multifactor productivity Unit labor costs
How the data are obtained	Estimated from multiple data sources
Classification system	Industry
Periodicity of data availability	Annual, Quarterly
Geographic detail	National
Scope	Private sector
Key products	• Productivity and costs • Multifactor productivity trends • Multifactor productivity trends in manufacturing
Program webpage	• www.bls.gov/lpc • www.bls.gov/mfp

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Concepts

This section defines key terms and concepts that are central to understanding how the Bureau of Labor Statistics (BLS) produces measures of productivity for different levels of the U.S. economy.

Productivity is a measure of economic performance that compares the amount of goods and services produced (output) with the amount of inputs used to produce those goods and services. BLS publishes two types of productivity measures: single-factor productivity and multifactor productivity. Labor productivity is the most widely used single-factor productivity measure.

Labor productivity is a measure of economic performance that compares the amount of goods and services produced (output) with the amount of labor hours worked to produce that output. Labor productivity is a ratio of output to hours worked. Therefore, a change in labor productivity reflects the change in output that is not explained by the change in hours worked. Labor productivity can increase over time for many reasons, including technological advances, improved worker skills, improved management practices, economies of scale in production, and increases in the amount of nonlabor inputs used (capital, energy, materials, and purchased services).

Measures of productivity are useful for tracking changes in efficiency and for determining the effects of technological change. Productivity analysis can also provide information to assess the impact of policy changes or external shocks on particular industries, and the resulting impact on economic growth of the larger economy. For productivity measurement, it is important that well-defined data on outputs and inputs exist, and that they are measured independently.

By the mid-1970s, there was a significant accumulation of research relevant to productivity measurement that had not yet been reflected in government measures. The idea of using production functions as a means of analyzing aggregate economic activity was pioneered by Paul Samuelson in 1947. In the following statement, the function, *f*, reflects the maximum amount of output (*Y*) that can be produced by various combinations of inputs of labor, *L*, and capital, *K*, given the technology available at time *t*:

$$Y = A_t f(K, L, t).$$

where,

K = capital services

L = labor input

t = time

A_t = technology available at time *t*

Y = output

A production function is typically the constraint on a model of optimizing behavior by the firm; given a set of prices, the firm determines the proportions of inputs which minimize cost, constrained by technology. Production functions also led to the formulation of macroeconomic growth models. During the 1950s and 1960s, growth models became increasingly sophisticated and detailed. In 1958, Robert Solow used a production function to show the role of capital in labor productivity trends. By assuming a production function and perfect competition in input factor markets, we can calculate the rate at which the production function is shifting, the growth in multifactor productivity (MFP), by differentiating by time as follows:

$$\frac{\Delta LN(A)}{dt} = \frac{\Delta LN(Y)}{dt} - s_L \frac{\Delta LN(L)}{dt} - s_K \frac{\Delta LN(K)}{dt}$$

where,

s_L and s_K are the average shares of labor and capital, respectively, in total cost over time and

$\frac{\Delta LN(I)}{dt}$ = the change in the natural log of *I* over time *t.*

We call the rate at which the function is shifting the growth rate of multifactor productivity. MFP is also referred to as total factor productivity or the “residual.” Solow showed that it follows that the rate of growth of labor productivity depends on the growth rate in the capital-labor ratio, weighted by capital’s share, and the growth rate of MFP:

$$\frac{\Delta LN(Y/L)}{dt} = \frac{\Delta LN(Y)}{dt} - s_K \frac{\Delta LN(K/L)}{dt} + \frac{\Delta LN(A)}{dt}$$

Multifactor productivity measures describe the relationship between output in real terms and the combined inputs involved in its production. Changes in multifactor productivity do not reflect the specific contributions of capital services, labor input, and energy, materials, and purchased services. Rather, multifactor productivity is designed to measure the joint influences on economic growth of a number of factors that are not specifically accounted for on the input side, including technological change, efficiency improvements, returns to scale, reallocation of resources, improved skills of the workforce, better management techniques, and other on economic growth, allowing for the effects of capital and labor.

BLS estimates MFP growth using a growth accounting framework that assumes Hicks-neutral technical change and constant returns to scale.[1]

The multifactor productivity indexes for private business and private nonfarm business are derived by dividing a value-added output index by an index of combined inputs of capital services and labor input. Value-added labor productivity growth is equal to MFP growth plus the growth in the capital-to-labor ratio (capital intensity) weighted by capital’s share of cost plus the growth in labor composition weighted by labor’s share of cost.

The multifactor productivity indexes at the industry level are derived by dividing a sectoral output index by an index of the combined inputs of labor, capital services, energy (*E*), materials (*M*), and purchased business services (*S*).

Output

Gross output is the total value of goods and services produced by an industry. Intermediate inputs are the foreign and domestically sourced goods and services used by an industry in the process of producing its gross output.

Value added is the difference between gross output and intermediate inputs and represents the cost of labor, capital, and taxes spent in producing gross output. The sum of value added across all industries in the economy is equal to gross domestic product for the economy.

Sectoral output is defined as gross output less intra-industry transactions. This measure defines output as deliveries to consumers outside the sector in an effort to avoid the problem of double-counting that occurs when one establishment provides materials used by other establishments in the same industry.[2]

Value-added output is used by BLS to measure productivity for aggregate sectors of the U.S. economy, including labor productivity in the business and nonfarm business sectors and multifactor productivity in the private business, and private nonfarm business sectors. At the National Income and Products Accounts (NIPA) industry level, labor and multifactor productivity are measured using a sectoral output concept.

The U.S. Bureau of Economic Analysis (BEA) calculates the measure of value-added output for the business sector by removing from GDP the gross product of general government, private households, and nonprofit institutions serving households. Output for these sectors is estimated primarily using data on labor compensation. The trends in such output measures will, by definition, move with measures of input data and will tend to imply little or no productivity growth. Therefore, BLS excludes these activities from aggregate value-added output in order to remove potential sources of bias specific to productivity measurement.

The measure of business-sector output used by BLS to measure productivity also excludes the value added of owner-occupied housing and the rental value of buildings and equipment owned and used by nonprofit institutions serving individuals. These components are excluded because no adequate corresponding labor input measures can be developed.

To measure multifactor productivity, BLS further restricts value-added output to the U.S. private business sector, which excludes the output of government enterprises. These enterprise data are removed because subsidies account for a substantial portion of capital income.

At the NIPA industry level, BLS uses a measure of sectoral output. The sectoral output measure defines output as deliveries to consumers outside the sector in an effort to avoid the problem of double-counting that occurs when one establishment provides materials used by other establishments in the same industry.[3] As a result, the sectoral output definition is more closely aligned with gross output at the most detailed industry level as intrasectoral transactions fall to zero. However, at the aggregate economy level, sectoral output and value-added output measures converge as the intermediate inputs produced and consumed within the sector approach the value of all intermediate input purchases.

By using sectoral output for NIPA industry productivity measures, advances in productivity in individual industries contribute to aggregate economic growth. This is done directly through increased deliveries to final demand and indirectly through increased deliveries to other sectors in the form of intermediate inputs.[4]

BLS makes estimates of multifactor productivity for the total economy available. For these measures, the BEA estimate of GDP must be modified to expand the output of government sectors and nonprofit institutions, to include more complete estimates of capital service inputs such as land. BLS replaces capital consumption allowances with measures of nominal capital services for government sectors and nonprofit institutions and adds that into GDP.

Inputs are the resources used in the production of goods and services and include labor, capital services, energy, materials, and purchased services. For labor productivity, output is compared only to labor hours worked to produce that output. For multifactor productivity private business and private nonfarm business, we compare value added output to the inputs of capital and labor. For NIPA industry level multifactor productivity measures, we use the KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) accounting framework that measures the sectoral output growth over and above the combined growth of these four inputs.

Labor hours and labor input

Hours worked is the total number of hours worked of all people in an industry or a sector. This includes paid employees, the self-employed (partners and proprietors), and unpaid family workers (those who work in a family business or farm without pay). In measuring productivity, it is appropriate to define “hours” as all hours spent working.[5] This includes all hours spent on actual production of goods and services, as well as time that is incidental to production, such as paid time for traveling between job sites, coffee breaks, and machine downtime. Paid vacations and other forms of paid leave are best viewed as benefits rather than as time available for production and should not be included for productivity analysis in measured hours.

Labor input is an aggregation of hours worked of the different types of workers with different skills and experience. BLS computes this as a measure of hours worked adjusted by a labor composition index that weights the heterogeneous class of workers by their median wage.

Labor composition measures the effects of shifts in the age, education, and gender of the workforce on hours worked. Not every work hour contributes the same amount to output. The productiveness of an hour of labor can differ based on age, education, and gender. The labor composition index adjusts the total hours worked for the demographic composition of those hours, which requires identification of separate, heterogeneous groups whose working hours are likely to have varying rates of output.

The labor composition model is formed by generalizing production function to permit numerous types of labor input. For the private business sector, this is written as:

$$Y = A_t f(k_1, \ldots, k_n, h_1, \ldots, h_m, t)$$

where,

Y = output

A_t = technology available at time t

k_i = n types of capital assets

h_i = m types of labor inputs

The above production function equation allows each type of labor input and each type of capital to have a specific effect on output. By taking the natural logarithm of both sides, differentiating with respect to time, and rearranging terms, the above equation can be expressed as the relationship between the multifactor productivity and the growth rate of output and the growth rates of the inputs:

$$\frac{\dot{A}}{A} = \frac{\dot{Y}}{Y} - \left(s_{k_1}k_1 + \cdots + s_{k_n}k_n + s_{h_1}h_1 + \cdots + s_{h_m}h_m\right)$$

where, the dot notation refers to the growth rate of that variable. The partial derivatives, s_{k_i} and s_{h_i}represent output elasticities, or the percent change in output as a result of 1-percent increase in the corresponding input. However, these marginal products are not observable in practice. Per the assumption of constant returns to scale and perfect competition in product and input markets, each elasticity is equal to the share of total costs paid to that input. For labor input, this is calculated as the share of the total wage bill that is spent on each particular type of labor. An aggregate labor input equation can be derived:

$$\frac{\dot{L}}{L} = s_{h_1}\frac{\dot{h}_1}{h_1} + \cdots + s_{h_m}\frac{\dot{h}_m}{h_m}$$

where, $\frac{\dot{L}}{L}$ is the instantaneous rate of change in composition-adjusted labor input, it can replaced by annual rates of change, calculated using the Törnqvist index method as the difference in the natural logarithm of successive observations, with weights equal to the average of the two period factor shares.

BLS partitions the Current Population Survey (CPS) sample into gender × age category × education level worker groups, and computes the year-to-year growth in hours for independent categories of worker. The growth rate in hours worked by class of worker are Törnqvist aggregated into a measure of total labor-input growth, where the weight for each group is its median wage. The growth rate of hours is then subtracted from the Törnqvist aggregated measure of labor-hours growth to obtain the labor-composition growth. This growth is used to adjust the official measures of BLS hours worked to include the effect of the changing composition of the workers in the multifactor productivity estimates.[6]

Annual indexes of labor composition are computed for private nonfarm business, private business and NIPA-level industries.

Capital input

Capital input, also known as capital services, is the flow of the services derived from physical assets (equipment, structures, inventories, and land) and intellectual property used to produce output.[7] Financial capital is not included in these measures. Capital services are derived by first computing productive capital stocks, then computing the rental prices of capital, and finally computing the composition index.

The productive capital stock is measured as the sum of past investments net of deterioration. Past investments are assumed to decline in productive capacity according to an *age-efficiency function*, (a,Ω)—where a is the age of the asset and Ω is its maximum service life—that represents the proportion of the investment's original productive capacity that remains at age a. Letting K_t denote the (net) productive capital stock of an asset in year t and I_{t-a} denote investment expenditures in year $t-a$ (that is, $t-a$ is the vintage of the asset), the productive capital stock for a group of identical assets that have a maximum service life of Ω is given by the following:[8]

(1)
$$K_t = \sum_{a=0}^{\Omega} \lambda(a,\Omega) I_{t-a}$$

BLS assumes a hyperbolic age-efficiency function, which we note as

$$\lambda(a,\Omega) = \frac{(\Omega - a)}{(\Omega - \beta a)} \quad \text{if } a < \Omega$$

(2)

$$\lambda(a,\Omega) = 0 \qquad \text{if } a \geq \Omega$$

where $\beta \leq 1$ is a shape parameter and $\lambda(\cdot)$ is concave, linear, or convex depending on whether $\beta \gtreqless 0$ (β = 1 implies one-hoss shay, for example a light bulb that works all the time until it doesn't work at all). BLS assumes β = 0.75 for structures and β = 0.5 for equipment.[9]

The age-efficiency function accounts for three avenues by which the productive capacity of a group of assets can decline. First, assets become physically less productive when used or require more downtime for maintenance or repairs. The second avenue is through obsolescence. The third is through failure. With all three of these avenues one would expect the age-efficiency function for an individual asset to be concave with respect to age.

The age-efficiency function in equation (2) assumes that all assets in the group have identical maximum service lives. However, assets within an asset group are heterogeneous and can be used differently, leading to different services lives. Thus, the investment data that BLS receive from BEA are for asset groups that contain similar assets, but likely have different maximum service lives.[10] Within an asset category, maximum service lives can differ because the assets are heterogeneous or because the assets are used differently. Therefore, within an asset group, BLS assumes a distribution of maximum service lives for each type of asset and computes a cohort age-efficiency function that is a weighted average of the deterioration functions of the individual asset types.[11]

The cohort age-efficiency function for an asset category is denoted by

$$\bar{\lambda}(a, \bar{\Omega}) = \int_{\Omega^{min}}^{\Omega^{max}} \tilde{\phi}(a, k) * \lambda(a, k) dk \quad (3)$$

where the limits of the integral are the upper and lower bounds of the distribution of service lives, where $\Omega^{min} = 0.02\bar{\Omega}$ and $\Omega^{max} = 1.98\bar{\Omega}$.

BLS assumes that $\tilde{\phi}(\cdot)$ is a modified truncated normal distribution with mean $\bar{\Omega}$ and $\sigma = 0.49\bar{\Omega}$. BLS truncates the normal distribution at ±2 standard deviations ($\bar{\Omega} \pm 0.98\bar{\Omega}$), shifting the density function downward so that it equals zero at the upper and lower bounds of the distribution, and then inflating the density function proportionately so that the final modified density, $\tilde{\phi}(\cdot)$, integrates to 1.

The final capital stock for each industry and asset-category combination is estimated by substituting equation (3) for the age-efficiency function in equation (1):

$$K_t = \sum_{a=0}^{\Omega^{max}} \bar{\lambda}(a, \bar{\Omega}) I_{t-a} \quad (4)$$

Note that the upper limit of the summation differs from that in equation (1). In equation (1), maximum service life refers to homogeneous assets with a maximum service life of Ω. But in equation (4), the maximum service life is the maximum of the longest lived asset in the asset category Ω^{max}. After the derivation of the capital stocks estimation of the rental price of capital begins.

The rental price of capital, or the user cost of capital, is the opportunity cost of holding and using it for a period of time. The industry considers investing in capital when the value of the marginal product of that investment is equal to the rental rate of capital.

For instance, when considering investing in a building, the investing industry knows it can earn returns over many years with a building. However, when it invests in a computer, the expectation of the industry is that the computer will be of only marginal usefulness in a few years. So industry must expect a dollar's worth of computer to yield services more intensely than a dollar's worth of building in order to justify the levels of investment in each.

Also, part of investment considerations are any taxes associated capital investment. The U.S. tax laws have varied from year to year, but they have generally favored investments in equipment by their tendency to make the effective cost of using equipment lower than the cost for structures. The laws accomplish this by allowing an investment tax credit for equipment and also by allowing depreciation deductions for equipment over very short periods of time. The rental price formula used by BLS includes a term which adds in property taxes assessed on the particular asset type, and a factor which adjusts the rental price for the effects on the returns to capital of the corporate income tax rate, depreciation deductions, and credits. This tax-adjusted rental price formula can be derived from the neoclassical assumption that the price of an investment good equals the discounted value of its future services plus the decline in the asset's value. The assumption is applied to a price which is adjusted for any tax credit and to a stream of after-tax future income.

In its simplest form, the rental price for a period is set to the price of the asset multiplied by the sum of the rate of depreciation and the appropriate rate of return:

$$c_t = p_t(r_t + d_t), \tag{5}$$

where,

c_t is the rental price for period t,

p_t is the price of the asset,

r_t is the rate of return, and

d_t is the rate of depreciation.

In addition to the price of asset, its rate of return and rate of depreciation BLS also accounts for inflation in the price of new assets and the effects of taxes. The BLS equation for the rental price is given by:

$$c_{ijt} = \frac{(1 - u_t z_t - e_t)\left(P_{j,t-1} r_{it} + P_{j,t-1} d_{ij,t} - \Delta P_{j,t-1}\right)}{1 - u_t} + P_{j,t-1} x_t \tag{6}$$

where,

u_t is the corporate income tax rate,

z_t is the present value of $1 of the depreciation deduction,

e_t is the effective rate of the investment tax credit (zero since 1979),

r_t is the nominal industry-specific internal rate of return on capital,

d_t is the average rate of economic depreciation of asset *j* in industry *i*,

$P_{j,t}$ is the asset-specific (for asset category *j*) deflator for new capital goods,

$\Delta P_{j,t}$ is the revaluation of assets due to inflation in new goods prices (asset category *j*), and

x_t is the rate of indirect taxes.

Rental prices are computed separately for each asset category and industry combination. Data are available, or easily calculated, for all of the variables in equation (6) except the internal rate of return, *r*.[12]

Wealth stock measures the financial value of the capital stock, rather than its productive capacity. Analogously, *depreciation* measures the decline in the financial value of the capital stock rather than the decline in its productive capacity. BLS calculates the wealth stock in order to estimate depreciation. Wealth and productive stock are linked through the age-efficiency function, with the main difference between the productive capital stock and the wealth stock is that the productive stock is a point-in-time measure (the current productive capacity of past investments), whereas the wealth stock is a forward looking measure (the discounted value of the remaining productive capacity of the productive capital stock).

The wealth stock is equal to the age-adjusted price of the asset multiplied by real investment summed over all asset cohorts that have positive productive capacity at time *t*:

$$(7) \qquad W_t = \sum_{\tau=t}^{2t} p(\tau - t, \bar{\Omega}) * I_{2t-\tau}$$

where $p(a, \bar{\Omega})$ is the price of an *a*-year-old asset (group) that has an average maximum service life of $\bar{\Omega}$. The age-price function is derived from the cohort age-efficiency function and is equal to the discounted value of the remaining productive capacity of the asset divided by the discounted value of the productive capacity of the asset over its entire service life:

$$(8) \qquad p(a, \bar{\Omega}) = \frac{\sum_{\alpha=a}^{2\bar{L}+1} \bar{\lambda}(\alpha, \bar{\Omega}) * (1-\rho)^{\alpha-a}}{\sum_{\alpha=0}^{2\bar{L}+1} \bar{\lambda}(\alpha, \bar{\Omega}) * (1-\rho)^{\alpha}}$$

where, $\bar{\lambda}(a, \bar{\Omega})$ is the cohort age-efficiency function equation (3), and ρ is the real discount rate, which is assumed to be 4 percent per year. The age-price function declines over time from 1, when the asset is new, to 0 at the end of its service life. It declines more quickly than the age-efficiency function, because the financial value of an asset declines—because of decreased remaining service life—even if its productive capacity does not.

The depreciation term is calculated as each year's constant dollar investment minus the change in the wealth stock.

Internal rate of return is calculated by setting capital income equal to the product of the capital stock (from equation 4 and the rental price of capital defined in equation 6 above):

$$(9) \qquad Y_{it} \equiv K_{it} c_{it},$$

where Y_{it} is nominal capital income in industry *i* and K_{it} is the productive capital stock in industry *i*. Substituting equation (6) for c_t and arranging terms the internal rate of return is:

$$(10) \qquad r_{it} = \frac{Y_{it} - xK_{it}P_{i,t-1} - K_{it}\left(P_{i,t-1}d_{it} - \Delta P_{i,t-1}\right)(1 - u_t z_t - e_t)/(1 - u_t)}{K_{it}P_{i,t-1}(1 - u_t z_t - e_t)/(1 - u_t)}$$

where $P_{i,t-1}$ is the industry level price deflator:

$$(11) \qquad P_{i,t-1} = \sum_{j \in J_i} \frac{K_{ij,t-1}}{\sum_{j \in J_i} K_{ij,t-1}} \cdot \frac{I^N_{ij,t-1}}{I^R_{ij,t-1}} = \sum_{j \in J_i} \frac{K_{ij,t-1}}{K_{i,t-1}} p_{j,t-1}$$

where J_i is the set of asset categories in industry *i*.[13]

An *external rate of return* is required when an implausibility arises with the capital income estimates. For instance, when the internal rate of return is negative due to large movements in the capital gains term. That, in turn, can drive the rental price negative and the capital costs negative, which would imply that someone was paying the industry to invest. Another reason BLS switched to using the rental price from the external rate of return instead of the internal rate of return is when abnormally large growth in the capital services are observed. A strangely behaving capital composition measure will also invoke the external rate of return, when the capital composition adjustment is abnormally large. Negative internal rates of return are the most common reason for using the external rate.

The proprietors' income line released by BEA reflects the *mixed income* of both proprietors' labor compensation as well as the capital income that proprietor will spend to build the business. Note that the capital income and components of value added are released by BEA and, for the labor compensation estimates, represent data for the employees only, not that of proprietors. BLS must divide the proprietors' mixed income into the two primary inputs to production, capital and labor. Independent estimates of proprietors' labor compensation and capital income are generated controlling to the total from the proprietors' income estimate from BEA.

The initial estimate of proprietors' labor compensation are made by assuming that the proprietors earn the same average hourly compensation as the employed workers. That compensation per hour estimate is multiplied by the number of proprietors to arrive at an independent measure of proprietors' labor. In addition, BLS assumes that the proprietors' capital rate of return is the same rate of return as their industry corporate counterparts allowing for an independent measure of capital income for the proprietors' piece of capital income. After these two independent measures are computed, BLS scales the sum to the mixed income figure reported by BEA, evenly distributing any residual.

Similar to the labor contribution, the contribution of capital inputs to output growth can be decomposed into the contributions of changes in the capital stock and changes in the composition ("quality") of the capital stock. The growth in *capital input* is calculated as a Törnqvist index of the growth of the productive capital stock for each asset, where the weights are the assets' shares of capital costs. The effect of *capital composition* on output growth is simply the share weighted growth in capital input minus the growth in the share weighted capital stock. This decomposition is exactly analogous to the decomposition of labor input into changes in hours worked and changes in the composition of the workforce.[14]

BLS assumes that the growth in capital inputs is approximately proportional to the growth of the capital stock. Capital input growth is a Törnqvist aggregation of capital stock growth rates weighted by each asset and industry combination's share of total capital cost (averaged over both years).[15]

Intermediate inputs, energy, materials and purchased services inputs

Intermediate inputs are components of energy, nonenergy materials, and purchased services. For productivity measures calculated using a sectoral output measure at a more disaggregate level, it is important to include both primary inputs (capital and labor) and intermediate inputs. Price and quantity indexes of intermediate inputs are obtained from BEA's annual industry accounts. As with the sectoral output measures, materials inputs and services are adjusted to exclude transactions between establishments within the same sector. These adjustments equal the adjustments made on the output side as well.

Combined inputs is a measure of all the inputs that are used by an industry to produce output. At the more aggregate level where value added analysis is the most appropriate tool for evaluating output growth, combined inputs include labor and capital. Inputs are combined using chained superlative Törnqvist aggregation, applying weights that represent each component's two period average share of total costs. For each input, the weight is the input's share of total costs and is derived from BEA data on the components of nominal value added 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 proprietor's income as mentioned previously. Most other components of nominal value added are assigned to capital. The exceptions are those taxes on production and imports which are not assigned to either capital or labor (notably sales and excise taxes).

Current dollar measures

Currently total cost is less than value added by an amount equal to these nonassigned taxes. Labor and capital shares in total cost are computed and then used in the aforementioned aggregation of capital and labor. The effect of computing the shares without taxes involved and applying that to the growth in the input and output statistics that have taxes embedded means that the nonassigned taxes are scaled across the inputs while maintaining their relative shares with each other.

For the more detailed sectors and industries where intermediate inputs have been shown to have an impact, sectoral output is used and the combined inputs include labor, capital, and the intermediate purchases of energy, materials, and purchased services.[16]

Labor compensation includes monetary and nonmonetary payments to or on behalf of individuals for labor services used to produce output. Workers may be employees, proprietors, and self-employed or unpaid family workers. Compensation of employees includes salaries, wages, bonuses, contributions to benefits plans, and other forms of payment. The compensation of employees in general government, nonprofit institutions, and private households are subtracted from compensation of employees in domestic industries to derive employee compensation for the business sector. For the nonfarm business sector, compensation further excludes farm employees. Proprietor's income is computed independently and scaled to control totals as described above.

Capital costs is the cost to produce output of goods and services that is attributed to the use of capital. It includes corporate capital income plus imputed proprietor's capital income. Corporate capital income includes the summation of corporate capital consumption allowances, corporate profits before tax without inventory valuation adjustment, corporate inventory valuation adjustment, corporate net interest and miscellaneous payments, corporate business transfer payments, and the part of taxes on production and imports associated with capital (property taxes and motor vehicle taxes). Proprietor's income and capital costs are independently estimated and scaled to BEA control totals of proprietor's mixed income described above.

Nonlabor payment is a measure of 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.

Unit labor costs measure the cost of labor input required to produce one unit of output and are derived by dividing hourly compensation of all persons in current dollars by the output per hour (labor productivity).

Unit nonlabor costs include the nonlabor components of value-added output in a given sector—consumption of fixed capital, taxes on production and imports less subsidies, net interest and miscellaneous payments, business current transfer payments, rental income of persons, and the current surplus of government enterprises—divided by the output index.

NOTES

[1] Robert M. Solow, "Technical change and the aggregate production function," *Review of Economics and Statistics* 39, no. 3 (August 1957), pp. 312–20.

[2] Further information on this concept of output, see William Gullickson, "Measurement of productivity growth in U.S. manufacturing," *Monthly Labor Review* (July 1995), pp. 13–27, https://www.bls.gov/mfp/mprgul95.pdf.

[3] Ibid.

[4] Further information on the intermediate input concept of relating aggregate growth through industry growth, see Frank Gollop, “Accounting for intermediate input: the link between sectoral and aggregate measures of productivity growth,” *Measurement and Interpretation of Productivity* (The National Academies Press, 1979), pp. 318, https://www.nap.edu/read/9578/chapter/18.

[5] Mary Jablonski, Kent Kunze, and Phillis Flohr Otto, “Hours at work: a new base for BLS productivity statistics,” *Monthly Labor Review*, (February 1990), https://www.bls.gov/opub/mlr/1990/02/art2full.pdf.

[6] Cindy Zoghi, “Measuring labor composition. A comparison of alternate methodologies,” *Labor in the New Economy* (University of Chicago Press, 2010), http://www.nber.org/chapters/c10834.pdf.

[7] For more information on capital inputs, see Lucy P. Eldridge, Chris Sparks, and Jay Stewart, “The U.S. Bureau of Labor Statistics productivity program,” *The Oxford Handbook of Productivity Analysis* (Oxford University Press, 2018), https://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780190226718.001.0001/oxfordhb-9780190226718-e-3 and Michael J. Harper, “Estimating capital inputs for productivity measurement: an overview of concepts and methods,” (paper presented at the Capital Stock Conference, March 10–14, 1997), http://www.oecd.org/sdd/na/2666894.pdf Passages are borrowed from and quoted throughout the capital input section as the authors of those sections were BLS employees at the time of the writings.

[8] BEA and many academic studies assume geometric deterioration, where the rate of deterioration is constant over time. This simplifies calculations, because this deterioration rate can be applied to the entire stock of capital, so there is no need to keep track of assets’ vintages. However, Michael Harper concluded that this assumption was unrealistic in many cases because assets’ productivity tend to decline slowly at first and more rapidly as they approach their maximum lifespans.

For more information on deterioration, see 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, and Michael Harper, “Estimating Capital Inputs for Productivity Measurement: An Overview of U.S. Concepts and Methods,” *International Statistical Review*, no. 3, 1999, pp. 327–37.

[9] These values were chosen because they are close to values estimated by Charles Hulten and Frank Wykoff using actual data.

[10]10 BEA provides the BLS with information on service lives and depreciation rates. BLS does not use BEA service lives. Instead, BLS estimates service lives so that, when used in conjunction with the hyperbolic age-efficiency function, they are consistent with BEA depreciation rates.

[11] Because average maximum service lives are estimates and there are no data about individual asset types with categories, the distribution can also be viewed as accounting for the uncertainty, as well as heterogeneity.

[12] Depreciation is calculated as the change in wealth stock minus the current year’s investment. The depreciation rate is equal to depreciation divided by the wealth stock, although in practice BLS uses the productive capital stock because it is less volatile than the wealth stock. The present value of $1 of tax depreciation allowance is calculated using equations from Robert Hall and Dale Jorgenson, and the deflator is calculated from the real and nominal investment data BLS gets from BEA. Use of

the internal rate of return is necessary because of the assumption of perfect competition, which requires that profits be zero in equilibrium.

For more information on depreciation, see Robert E. Hall and Dale Jorgenson, "Tax policy and investment behavior," *American Economic Review*, (June 1967), http://web.stanford.edu/~rehall/Tax-Policy-AER-June-1967.pdf

[13] Note that equation (6) is defined for an industry × asset combination, whereas the rental price in equation (9) is defined for an industry only. Since capital income is available only at the industry level, equation (6) is modified using equation (11) so that the rental price used in the derivation of equation (10) is defined at the industry level.

[14] Capital input can also be decomposed by type of asset to show the portion of capital input attributable to each type of asset.

[15] This description glosses over many details. The Törnqvist aggregation is done in two steps, with the BEA asset categories being aggregated into seven asset groups for each industry (equipment, structures, land, rental residential capital, inventories, intellectual property products, and "all assets"). These asset group × industry combinations are then combined using the Törnqvist formula to arrive at the required intermediate and final aggregates.

[16] Frank Gollop, "Accounting for intermediate input: the link between sectoral and aggregate measures of productivity growth," *Measurement and Interpretation of Productivity* (National Academy of Productivity 1979), pp. 332, https://www.nap.edu/read/9578/chapter/18#332.

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Data Sources

Major Sector Productivity collects data from a variety of different sources. For almost all sectors and industries, output is measured using a different source than inputs (capital, labor, and intermediate inputs purchases). Below is information on data sources for measuring the components of labor productivity and multifactor productivity.

Output

The output index used to calculate productivity differs depending on the level of the economy being measured.

For business, nonfarm business, private business, and private nonfarm business the output index is prepared using real value added measures that are published by the Bureau of Economic Analysis (BEA). These output measures are based on and are consistent with the National Income and Product Accounts (NIPA), including the gross domestic product (GDP) measure, also prepared by the BEA.[1] BEA calculates quarterly and annual measures of business sector output by removing from GDP the value added of general government, private households, and nonprofit institutions serving households. These measures, and the measures of nonfarm business sector output, are the real output series used to calculate Bureau of Labor Statistics (BLS) measures of labor productivity in the U.S. business and nonfarm business sectors. To measure multifactor productivity, BLS further restricts output to the U.S. private business sector, excluding the output of government enterprises. The BLS multifactor productivity statistics for the private business and private nonfarm business sectors are constructed using annual BEA output data.

At the NIPA industry level, including manufacturing durable and nondurable sectors, the annual output index used is a sectoral output measure based on data obtained from the Bureau of the Census. Output indexes for industries within the manufacturing sector use current-dollar industry value of production with intraindustry transactions removed and is deflated using prices from the BLS Producer Price Index program. For some nonmanufacturing industries, physical quantities of output are measured using data from the Department of the Interior and the Department of Transportation. For the remainder of nonmanufacturing industries output is prepared with data from the BEA. See table A for industry specific data sources.

Quarterly indexes of manufacturing output underlying the quarterly labor productivity data are estimated using the annual manufacturing of sectoral output based on census data and Indexes of Industrial Production, prepared by the Board of Governors of the Federal Reserve System. Because of a lag in the availability of the annual benchmark data, recent quarterly and annual manufacturing output measures also are extrapolated on the basis of the changes in the Indexes of Industrial Production.

Inputs

Hours worked. The primary source of hours and employment data is the BLS Current Employment Statistics (CES) program, which provides monthly survey data on employment and average weekly hours in nonagricultural establishments. CES data on the number of jobs held by wage and salary workers in nonfarm establishments are supplemented with data from the Current Population Survey (CPS) on self-employed and unpaid family workers to estimate total worker hours for each industry. CES data on the average weekly hours paid of workers are supplemented with CPS data on hours of nonproduction, self-employed, and unpaid family workers. Ratios of hours worked to hours paid are developed using data from the National Compensation Survey (NCS) and the BLS Hours at Work Survey.

Although the hours worked of all persons are usually based on CES and CPS survey data, estimates for some industries are derived from other sources. Estimates of hours for government enterprises and nonprofit corporations are calculated using data from the BEA. For quarterly labor productivity, hours of employees in the farm sector are derived from data from the CPS. For multifactor productivity, hours for this sector are based on USDA farm survey data.

Labor composition. For multifactor productivity, hours worked measures are adjusted for labor composition using data from the CPS. BLS partitions the CPS sample into gender × age category × education level worker groups, and computes the year-to-year growth in hours for independent categories of worker, weighted by work wages.

Labor compensation. Current dollar labor compensation measures are prepared using employee compensation data from the BEA. Compensation data includes wage and salary accruals (including executive compensation), commissions, tips, bonuses, and payments in kind representing income to the recipients—and supplements to these direct payments. Supplements consist of employer contributions to funds for social insurance, private pension and health and welfare plans, compensation for injuries, etc. For labor productivity, self-employed compensation per hour is assumed to be equal to employee compensation per hour.

For multifactor productivity, self-employed compensation is derived from proprietor's income from BEA. Proprietor's income includes both capital and labor income. An initial value of labor compensation per hour for proprietors is assumed to be the same as that of the average payrolled employee in that sector. Capital income and labor compensation initial estimates are then adjusted to be consistent with the value added estimates from the Industry accounts at BEA in addition to the proprietor's income measure published by the BEA NIPA.

Measures of real compensation per hour are derived by adjusting hourly compensation for changes in consumer prices. The price changes for recent quarters are based on the BLS Consumer Price Index for All Urban Consumers (CPI-U). For earlier periods consumer prices are based on the BLS Consumer Price Index research series (CPI-U-RS).

Capital services. For depreciable assets, capital services measures are based on data from the BEA fixed asset accounts by detailed asset, and GDP by industry.

Nondepreciable assets, such as inventories and land, stocks are developed using data from BEA and the Internal Revenue Service. Farm land input is based on data from the Economic Research Service of the U.S. Department of Agriculture.

Intermediate inputs. Data on intermediate inputs—energy, materials, and purchased services—are derived from measures based on the BEA industry accounts.

Exhibit 1. KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) measures of industry output data sources for Multifactor Productivity (MFP)

Industry title	Source
Farm sector	BEA GDP by industry
Forestry, fishing, and related activities	BEA GDP by industry
Oil and gas extraction	Energy Information Administration
Mining, except oil and gas	Energy Information Administration
Support activities for mining	Energy Information Administration
Utilities	Energy Information Administration
Construction	BEA GDP by industry
Wood products	Census Annual Survey of Manufactures
Nonmetallic mineral products	Census Annual Survey of Manufactures
Primary metal products	Census Annual Survey of Manufactures
Fabricated metal products	Census Annual Survey of Manufactures
Machinery	Census Annual Survey of Manufactures
Computer and electronic products	Census Annual Survey of Manufactures
Electrical equipment, appliances, and components	Census Annual Survey of Manufactures
Transportation equipment	Census Annual Survey of Manufactures
Furniture and related products	Census Annual Survey of Manufactures
Miscellaneous manufacturing	Census Annual Survey of Manufactures
Food and beverage and tobacco products	Census Annual Survey of Manufactures
Textile mills and Textile product mills	Census Annual Survey of Manufactures
Apparel and leather and applied products	Census Annual Survey of Manufactures
Paper products	Census Annual Survey of Manufactures
Printing and related support activities	Census Annual Survey of Manufactures
Petroleum and coal products	Energy Information Administration
Chemical products	Census Annual Survey of Manufactures
Plastics and rubber products	Census Annual Survey of Manufactures
Wholesale trade	BEA GDP by industry
Retail trade	BEA GDP by industry
Air transportation	Department of Transportation
Rail transportation	BEA GDP by industry
Water transportation	BEA GDP by industry
Truck transportation	Census Services Annual Survey
Transit and ground passenger transportation	BEA GDP by industry
Pipeline transportation	BEA GDP by industry
Other transportation and support activities	BEA GDP by industry
Warehousing and storage	BEA GDP by industry
Publishing industries, except internet [includes software]	Census Services Annual Survey
Motion picture and sound recording industries	BEA GDP by industry
Broadcasting and telecommunications	Census Services Annual Survey
Data processing, internet publishing, & other info services	BEA GDP by industry
Federal reserve banks, credit intermediation, & related activities	BEA GDP by industry
Securities, commodity contracts, and investments	BEA GDP by industry
Insurance carriers and related activities	BEA GDP by industry
Funds, trusts, and other financial vehicles	BEA GDP by industry
Real estate	BEA GDP by industry

Exhibit 1. KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) measures of industry output data sources for Multifactor Productivity (MFP)

Industry title	Source
Rental and leasing services and lessors of intangible assets	BEA GDP by industry
Legal services	BEA GDP by industry
Computer systems design and related services	BEA GDP by industry
Miscellaneous professional, scientific, and technical services	BEA GDP by industry
Management of companies and enterprises	BEA GDP by industry
Administrative and support services	BEA GDP by industry
Waste management and remediation services	BEA GDP by industry
Educational services	BEA GDP by industry
Ambulatory health care services	BEA GDP by industry
Hospitals and nursing and residential care facilities	BEA GDP by industry
Social assistance	BEA GDP by industry
Performing arts, spectator sports, museums, & related activities	BEA GDP by industry
Amusements, gambling, and recreation industries	BEA GDP by industry
Accommodation	Census Services Annual Survey
Food services and drinking places	Census Services Annual Survey
Other services, except government	BEA GDP by industry

NOTES

[1] A summary of the source data and methods used to estimate current-dollar Gross Domestic Product (GDP) and real GDP is provided by the Bureau of Economic Analysis in "Updated summary of NIPA methodologies," *Survey of Current Business* (Bureau of Economic Analysis, November 2007), pp. 8–25. Also, see "An introduction to the National Income and Product Accounts" (Bureau of Economic Analysis, September 2007). The current chain-type annual-weighted quantity measures are discussed in J. Steven Landefeld and Robert P. Parker, "BEA's chain indexes, time series, and measures of long-term economic growth," *Survey of Current Business* (Bureau of Economic Analysis, May 1997), pp. 58–68. The 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* (Bureau of Economic Analysis, July 1995), pp. 31–38. These BEA articles may be found on their website (https://apps.bea.gov/scb/).Derivation of business sector output is also discussed in Edwin R. Dean, Michael J. Harper, and Phyllis Flohr Otto, "Improvements to the quarterly productivity measures," *Monthly Labor Review*, (October 1995), pp. 27–32, https://www.bls.gov/opub/mlr/1995/10/art4full.pdf.

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Design

Major Sector Productivity does not conduct a survey to collect data. Rather, data on major sector and industry inputs and output is drawn from other publically available sources. These sources include (but are not limited to) Bureau of Labor Statistics data on employment and hours, and Department of Commerce data on output, compensation, and capital. For more information, please see the Data sources section.

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Calculation

Productivity statistics describe how efficiently an industry or sector produces goods and services. Measures of productivity are calculated by independently calculating inputs and outputs. A change in the quantity of output that is not explained by an equivalent change in inputs is defined as growth (or decline) in productivity. The following section will describe the mathematical principles and techniques by which industry output, inputs, and productivity series are measured.

Labor productivity, or output per hour, is computed as an index of real output divided by an index of hours worked:

$$(1) \quad \text{Labor productivity} = \left(\frac{\text{Output index}}{\text{Hours worked}}\right)$$

Multifactor productivity (MFP) is computed as an index of real output divided by an index of combined inputs used to produce that output. Inputs can include labor, capital, energy, materials, and purchased services.

$$(2) \quad \text{MFP} = \left(\frac{\text{Output index}}{\text{Combined inputs}}\right)$$

Output

Real business sector output is an annual-weighted (Fisher-Ideal) index constructed by the Bureau of Economic Analysis (BEA) 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. This measure, and the measure of nonfarm business sector output, which also excludes farm output, are the real output series used to calculate Bureau of Labor Statistics (BLS) measures of labor productivity in the U.S. business and nonfarm business sectors, using both quarterly and annual BEA output data. To measure multifactor productivity, BLS further restricts output to the U.S. private business and private nonfarm business sectors, which exclude the output of government enterprises. BLS multifactor productivity statistics for the private business and private nonfarm business sectors are constructed using annual BEA output data.

Annual manufacturing output indexes for both labor productivity and multifactor productivity measures are constructed by deflating the current-dollar industry value of production published by the U.S. Bureau of the Census along with data published by BEA. Industry shipment data are converted to a current dollar production basis by adjusting for the inventory and resale values. These data are converted to a sectoral output basis by removing the intra-industry transactions. The output index for manufacturing is constructed using a chained superlative index (Törnqvist) of three-digit North American Industry Classification System (NAICS) industry outputs. This index formula aggregates the growth rates of detailed primary and secondary industry outputs between two periods, using their relative shares in industry value of production averaged over the two periods as weights.

Quarterly indexes of manufacturing output underlying the quarterly labor productivity data are estimated using the annual manufacturing indexes and monthly Indexes of Industrial Production, prepared by the Board of Governors of the Federal Reserve System (FRB). To derive quarterly estimates from the annual manufacturing indexes, a quarterly reference series, constructed from the FRB indexes, is adjusted to the annual totals using a quadratic minimization formula devised by Frank Denton.[1] Because of a lag in the availability of the annual benchmark data, recent quarterly and annual manufacturing output measures also are extrapolated based on the changes in the Indexes of Industrial Production.

Labor hours

For labor productivity, real output is compared to the number of hours worked in a sector. Total quarterly and annual hours worked are estimated separately for three categories: paid employees, self-employed, and unpaid family workers. Employees account for about 90 percent of hours worked. Seasonally adjusted monthly data on employment and average weekly hours of all employees, and of production and nonsupervisory employees only, are provided by the BLS Current Employment Statistics (CES) program for 83 three-digit-level NAICS industries in the private nonfarm sector. Employment of nonproduction or supervisory workers in each industry is found by subtracting employment of production workers from employment of all employees.

CES average weekly hours are collected on an hours-paid basis, including time when employees are not at work. Therefore, ratios of hours worked to hours paid by three-digit NAICS industry from the BLS National Compensation Survey (NCS) are applied to the average weekly hours of production workers. This adjustment ensures that changes in vacation, holiday, and sick pay do not affect growth in hours. More formally, hours worked by production workers and nonsupervisory (P) workers are given by:[2]

$$(3)\ \ Hours\ worked_p = AWH_p^{CES} \times hwhp^{NCS} \times Emp_p^{CES} \times 52$$

where,

$Hours\ worked_p$ = hours worked by production workers

AWH_p^{CES} = average weekly hours of production workers from the CES

$hwhp^{NCS}$ = hours worked to hours paid ratio from the NCS

Emp_p^{CES} = production worker employment from CES

52 = weeks in the year used to get an annualized value

For supervisory workers, ratios of average weekly hours worked by supervisors to average weekly hours worked by production workers at the 14-sector level are derived from data on hours worked collected by the Current Population Survey (CPS). These ratios are applied to the average weekly hours worked by production workers after they have been aggregated to a 14-sector level to estimate average weekly hours worked by supervisory workers. For each sector, the hours of non-production and supervisory workers (*S*) are calculated as follows:

$$(4)\ \ Hours\ worked_S = (\ AWH_P^{CES} \times hwhp^{NCS}) \times \frac{AWH_S^{CPS}}{AWH_P^{CPS}} \times Employment_S^{CES} \times 52$$

Hours worked for the two worker groups (equations 3 and 4) are summed to all-employee hours for each of the fourteen sectors, then aggregated to private nonfarm employee hours worked.

To measure the business sector, the private nonfarm hours worked series must be further adjusted to exclude nonprofit institutions. The Economic Census is published every 5 years and provides employment by tax status of the employer. The BLS Office of Productivity and Technology (OPT) uses tax-exempt status as a proxy for nonprofit status. To exclude nonprofit employee hours, ratios of tax-exempt employment to total employment (from the Economic Census) are calculated at the three-digit level. For some industries these ratios are estimated using BEA data on compensation of employees by tax status.

$$(5)\ \ nonprofit_i\ = \frac{(Tax\ exempt\ employment)_i}{(Taxable\ employment + Tax\ exempt\ employment)_i}$$

Employment and hours worked of production workers in each 3-digit industry are multiplied by the nonprofit ratio:

$$(6)\ \ Hours\ worked_P^{Business} = \sum_i Hours\ worked_{P,i} \times (1 - nonprofit_i)$$

$$(7)\ \ Employment_P^{Business} = \sum_i Employment_{P,i} \times (1 - nonprofit_i)$$

where,

i = three-digit level industry.

After the production worker data are aggregated to the 14-sector level, average weekly hours for production workers in the business sector, $AWH_P^{Business}$, are derived as the ratio of hours divided by employment. Supervisory worker hours in the business sector can then be calculated as follows:

$$(8)\ \ Hours\ worked_S^{Business} = (\ AWH_P^{Business} \times hwhp^{NCS}) \times \frac{AWH_S^{CPS}}{AWH_P^{CPS}} \times Emp_S^{CES} \times 52$$

Again, hours worked by the two worker groups are summed to obtain hours worked by employees excluding employees of nonprofit institutions by sector, then aggregated to yield hours worked in private nonfarm business sector:

$$(9)\ \ Hours\ worked_{all}^{Business} = \sum\nolimits_{j} (\ Hours\ worked_{P}^{Business} + \ Hours\ worked_{S}^{Business})_{j}$$

where,

j = 14-sector level sector.

For the nonfinancial corporate sector, noncorporate and financial employees are excluded in addition to employees of nonprofit institutions. Employees in the financial industries are simply excluded from the aggregation. Estimating corporate employee hours is similar to the approach used for nonprofits; corporate employment ratios are calculated by dividing corporate employment by total employment from data reported by the Economic Census. These ratios are applied to both production and supervisory employee hours worked at the three-digit industry level, then the adjusted measures are aggregated to nonfinancial corporate sector hours.

Hours worked by employees of government enterprises must be estimated, and added to private nonfarm business employee hours, to yield hours worked by all employees in the nonfarm business sector. Annual employment in federal, and state and local, government enterprises from the National Income and Products Account (NIPA) is combined with monthly data from the CES on federal, state, and local employment, and from the CPS on average weekly hours of related workers—federal postal workers and state and local public administration workers excluding education—to estimate hours of these employees.

Employee hours worked must be supplemented with hours worked by self-employed and unpaid family workers to yield measures of hours worked by all persons in the published sectors. The CPS provides hours worked by the self-employed and unpaid family workers in both the nonfarm and farm sectors, and by farm employees.[3]

Seasonal adjustment

All uses of monthly CPS data start from not-seasonally-adjusted data, which are seasonally adjusted by OPT. The Census X-12-ARIMA Seasonal Adjustment Program Method is used to create monthly and quarterly seasonally adjusted data. The X-12 method modifies the X-11 variant of the Census Method. Currently, 4 of the 17 CPS source data series are not seasonally adjusted because they exhibit no identifiable seasonal pattern. OPT employs concurrent seasonal adjustment of CPS-based measures, and revises two prior months of data each time a new month of data is added. This mirrors the BLS practice of revising two prior months of CES data on employment and average weekly hours of employees each month. Each January, when another year of monthly or quarterly data is completed, each series is analyzed to identify the best seasonal adjustment parameters. These parameters are then locked in for the coming calendar year. Seasonally adjusted CPS data are not revised for prior years. Seasonally adjusted monthly CPS data are averaged to get quarterly and annual measures of hours worked by self-employed and unpaid family workers. Hours of these workers are added to the hours worked by paid employees to obtain hours worked by all persons in each of the industries or major sectors for which BLS measures and publishes productivity.

Labor input

Labor input is an aggregation of hours worked by different types of workers with different skills and experience. BLS computes this as a measure of hours worked adjusted by a labor composition index which weights the heterogeneous class of workers by their median wage.[4]

$$(10) \quad \Delta \mathrm{LN}(labor\ input)_t = \Delta\,\mathrm{LN}(labor\ composition)_t + \Delta\,\mathrm{LN}(Hours\ worked)_t$$

This adjustment is part of the calculation of multifactor productivity. BLS computes the labor composition using data from the CPS that are scaled to published CES estimates.

BLS partitions workers into 70 different categories depending on a worker's age, gender, and level of education. There are seven age categories, five education categories, and two gender categories. (See exhibit 1.)

Exhibit 1. Labor composition categories

Age Age group	Age group	Education level	Education group	Gender
16–18	1	Less than a high school diploma	1	Male
19–24	2	A high school diploma (or GED)	2	Female
25–34	3	Some college	3	
35–44	4	A college degree	4	
45–54	5	More than a college degree	5	
55–64	6			
65+	7			

BLS uses age, gender, and education levels as proxies for experience and ability. Age is used as a proxy to measure years of potential experience, in that workers, in a given age × education cell will have similar levels of potential labor market experience.[5] Male and female designations are included as a stratifying variable to account for the differential returns to potential experience and for the different occupational choices of men and women (which could be the result of preferences or discrimination).[6]

Individuals in age group 1 with a college degree or higher are a special case because there are very few 16- to 18-year-olds with a college degree or higher. These workers are promoted to the 19- to 24-year-olds group 2.

The sample includes all *employed persons* who worked during the reference week and were classified as in-scope. Those who were employed but did not work during the reference week are included when estimating wages but not when aggregating hours.

To measure the growth in *hours worked*, BLS uses actual hours worked during the previous week. For each demographic cell, total annual hours are calculated as follows:

$$(11) \quad Annual\ Hours^{CPS} = Average\ Monthly\ Employment^{CPS} * Average\ Weekly\ Hours^{CPS} * 52$$

If an *hourly wage* is reported to CPS, the hourly wage is used. If an hourly wage is not reported, the hourly wage is calculated as usual weekly earnings divided by usual weekly hours (both on the main job). If usual weekly hours is reported as "hours vary," actual weekly hours are used.[7] These wages are used to calculate total labor costs and cost-share weights for each cell. The CPS files do not have earnings data for self-employed workers or for second jobs. For labor composition calculations, BLS assumes that these workers earn the same hourly wage as wage and salary workers in the same estimating cell.

Ratio adjustments

Data on industry and hours data for second jobs (for multiple jobholders) is available starting in 1994. Before 1994, hours on both jobs were reported together, and all hours were attributed to the first job's industry. For these years, BLS calculates a ratio—by industry using 1994 data—that relates hours worked first and second jobs to the hours that would have been attributed to the industry in the pre-1994 data:[8]

$$(12)\ \ Ratio = \frac{1994\ sum\ of\ actual\ hours\ worked\ at\ 1st, 2nd\ jobs\ in\ an\ industry}{1994\ actual\ hours\ worked\ all\ jobs\ attributed\ to\ 1st\ job's\ industry}$$

This ratio is used to reweight individual observations in 1993 and earlier years.

Prior to 1994, it was not possible to distinguish between private employees at for-profit and nonprofit establishments. BLS calculates an industry-level ratio adjustment to remove employees of nonprofits. This ratio is calculated using 1994 data and is applied to the pre-1994 data:

$$(13)\ \ Ratio = \frac{1994\ total\ private, for\ profit, employment\ in\ an\ industry}{1994\ total\ private, for\ profit\ and\ nonprofit, employment\ in\ an\ industry}$$

Törnqvist aggregation

BLS uses growth in hours and two-period-average labor-cost shares to calculate a Törnqvist index of labor input. The labor composition adjustment is the difference between the growth in labor input and the growth in total labor hours. To calculate labor composition, the labor cost of a group (both of each cell and the total industry) are estimated:

$$(14)\ \ Labor\ cost\ =\ median\ hourly\ wage * total\ annual\ hours$$

Cost share weights for the Törnqvist index are calculated for each demographic cell as that cell's share of total labor cost. In each cell, total labor cost is calculated as the median wage times total hours.[9] Share weights are equal to the cell's total labor cost divided by aggregate labor cost. The medians are calculated on an hours weighted basis using a modified version of the BLS interval method for calculating median hourly wages, and can be thought of as the wage of the median hour worked.

Next, the annual cost share for all cells within an industry or sector is computed:

$$(15)\quad Annual\ cost\ share(s_j) = \frac{labor\ cost\ of\ a\ cell}{labor\ cost\ of\ an\ industry}$$

The growth in labor input within an industry or sector is calculated as follows:

$$(16)\quad \Delta \ln Labor\ Input_t = \sum_{j \in J} \frac{1}{2}\left(s_{j,t} + s_{j,t-1}\right)\Delta\,\mathrm{LN}(Hours\ worked)_{j,t}$$

where,

$s_{j,t}$ = Cost share of demographic group *j* in time *t.*

Changes in the index of labor composition are defined as the difference between the change in composition-adjusted hours given in (equation 16), and the change in the unadjusted (unweighted) hours of all workers can be shown by rearranging (10):

$$(17)\quad \Delta \ln Labor\ composition_t = \Delta \ln Labor\ input_t - \Delta \ln Hours\ worked_t$$

The index is calculated by chaining the annual growth rates to the base year.

Note that for a cell to be included in the calculation, it must have a matching cell for the prior year in order to measure growth over time. BLS employs data estimation techniques and multiple imputations to fill in missing observations and where data are too thin to adequately evaluate. 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 two-period-average share of total wages. 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 age and education) of the work force.

Capital input

Capital input, also known as capital services, is estimated by calculating productive capital stocks; capital services are assumed to be proportional to changes in the quantity of capital stocks for each asset. The capital index is a Törnqvist index of separate quantity indexes of equipment, structures, inventories, and land.

Capital stocks are composed of numerous different assets purchased at different times, which fall within the categories of equipment, structures, inventories, or land. The measure of capital stock for each year includes that year's investment in an asset plus the remaining productive stock from all previous years' investments. Capital stocks of equipment and structures for each industry 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 occur. Real (constant dollar) investments in various assets are estimated by deflating current dollar investments with appropriate price deflators. The perpetual inventory method measures real 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:

$$(18)\ \ Asset\ efficiency_t = (Asset\ service\ life - t)/(Asset\ service\ life - (\beta)t)$$

where,

t = the age of the asset, and

β = the parameter of efficiency decline.

The service life of the asset for each cohort of each type of equipment and structure is assumed to be normally distributed around an average service life for that asset type. For most assets, these service lives are the same across all industries. The parameter of efficiency decline is assumed to be 0.5 for equipment and 0.75 for structures.[10]

These parameters yield a function in which assets lose efficiency more slowly at first, and then lose efficiency more rapidly later in their service lives.

The annual inventory stocks for finished goods, work in process, and materials and supplies are calculated by using a weighted average, including five quarterly inventory numbers.

Various equipment, structure, inventory, and land stock series in constant dollars are aggregated into one capital input measure using a Törnqvist formula. Capital stocks multiplied by implicit rental prices yield cost share weights.

Rental prices are calculated for each asset as:

$$(19)\ \ Rental\ price = [(P * R) + (P * D) - \Delta(p)](1 - uz - k)/(1 - u)$$

where,

P = deflator the the asset,

R = internal rate of return,

D = rate of depreciation for the asset,

Δp = capital gain term representing the price change of the asset over the prior three years,

$$\frac{(1 - uz - k)}{(1 - u)} = \text{ tax,}$$

$u = \text{the corporate tax rate, and}$

$z = \text{ present value of \$1 of depreciation deduction} = \text{ effective investment tax credit rate.}$

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 asset-specific capital costs, the shares of which are used for Törnqvist aggregation.

The stock of *research and development* (R&D) in private nonfarm business is obtained by cumulating constant dollar measures of research and development expenditures net of depreciation. BLS develops price deflators and also estimates the rate of depreciation of R&D.[11]

Capital intensity is the ratio of capital services to hours worked in the production process. The higher the capital to hours ratio, the more capital intensive the production process becomes.

$$(20)\;\; Capital\ intensity = \frac{Capital\ services}{Hours\ worked}$$

Intermediate inputs of production

Intermediate inputs consist of energy, materials, and purchased business services and represent a large share of production costs. Data on intermediate inputs are obtained from BEA based on BEA annual input-output tables. Törnqvist indexes of each of these three input classes are derived at the roughly three-digit NAICS level. Materials inputs are adjusted to exclude transactions between establishments within the same goods producing sector.

Combined inputs of production

BLS aggregates inputs for its multifactor productivity measures using a Törnqvist chain index method. This index 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. For example, the index of inputs (I) in each year, *t*, for major sectors, in which output is value added, is calculated by linking to the previous year's index:

$$(21)\;\; \Delta \ln Combined\ inputs_t = \sum_{j \in K,L} \frac{1}{2}\left(s_{j,t} + s_{j,t-1}\right) \Delta \ln input_{j,t}$$

where,

$s_{j,t}$= share of input *j* in time *t*.[12]

Multifactor productivity

For the private business and private nonfarm business where output is measured as value added, the multifactor productivity (MFP) growth can be expressed in the following way:

$$(22)\ \ \Delta MFP = \Delta Value\ added\ output\ - sK\frac{\Delta K}{K} - sL\frac{\Delta L}{L}$$

where,

s_j = average two period share of costs of input *j* divided by output,

K = real capital services, and

L = labor input.

Whereas the 60 NAICS industry multifactor productivity uses a sectoral output concept which includes the intermediate inputs of energy, materials, and purchased business services along with the primary inputs of capital and labor input. This can be written in the following way:

$$(23)\ \ \Delta MFP = \Delta Sectoral\ output\ - s_K\frac{\Delta K}{K} - s_L\frac{\Delta L}{L} - s_E\frac{\Delta E}{E} - s_M\frac{\Delta M}{M} - s_S\frac{\Delta S}{S}$$

where,

s_j = average two period share of costs of input *j* divided by output,

K = Capital input

L = Labor Input- including the effects of both labor composition and hours

E = real energy input,

M = real materials, and

S = real purchased services.

For private business and private nonfarm business, the relationship of aggregate multifactor productivity to aggregate labor productivity can be further explored by the following equation:

$$(24)\quad \frac{\Delta LN(\frac{Output}{Labor\ Hrs})}{dt} = \frac{\Delta LN(A)}{dt} + s_K \frac{\Delta LN\left(\frac{Capital}{Labor\ Hrs}\right)}{dt} + s_L \frac{\Delta LN(Labor\ Composition)}{dt}$$

where,

s_j = average two period share of costs of input *j* divided by output,

$\left(\frac{Capital}{Labor\ Hrs}\right)$= capital intensity = capital input divided by labor hours,

$\left(\frac{Output}{Labor\ Hrs}\right)$= labor productivity, and

A = multifactor productivity.

This equation shows that labor productivity growth is decomposed into multifactor productivity growth, the contribution resulting from *K/L* substitution (capital deepening) and the contribution of the labor composition effect. Thus, labor productivity grows because of shifts in the production function, *A*, because of increases in capital intensity, and shifts in the composition of workers.

For industries and NAICS NIPA-level industry, labor productivity growth also results from the contribution resulting from intermediate inputs.

Preliminary multifactor productivity

Measures for the most recent year of the multifactor productivity trends are preliminary. A simplified methodology is used to estimate preliminary multifactor productivity change in the private business and private nonfarm business sectors. The simplified method uses preliminary data to estimate 1 additional year of data past the reference year. The simplified methodology involves making estimates of the growth rates of output, labor input and capital input, and of the shares of each input. Using the same basic structure and assumptions, the simplified methodology is designed to yield estimates of multifactor productivity approximating closely those calculated by the full methodology. The simplified methodology includes fewer categories of capital than the full methodology. The simplified measure is usually based on information from the full calculation from the previous year and on up-to-date information on hours worked from BLS and output and capital from NIPA and other sources available early in the year following the target year. The resulting simplified measure will later be updated when more complete source data become available. In practice, the revision of the simplified estimate to obtain a full estimate reflects both the difference in methodologies and concurrent revisions to the underlying source data.[13]

Costs of production

The production function specifies a certain set of output given a certain set of inputs. On a current dollar basis this production equates from paying the factors of production their marginal cost. Below are the costs associated with the value of production.

Labor compensation

Total quarterly and annual labor compensation are estimated separately for two categories: paid employees and self-employed. Detailed measures of current dollar employee compensation come from the BEA national accounts. To construct an estimate of employee compensation for the business sector, BLS subtracts compensation of employees of general government, nonprofit institutions, private households, and compensation paid to foreign residents from total employee compensation. These components are part of the BEA's estimates of national income. BLS estimates compensation of self-employed workers by assuming their compensation per hour is equal to that of the employees in the same sector. Self-employed compensation is calculated by multiplying the compensation per hour of the paid employees by the hours worked of self-employed. The compensation of the two categories of paid employees and the self-employed are then summed to obtain a total compensation measure.

In the estimation of self-employed compensation for the multifactor productivity program, a similar set of assumptions are made but are then controlled to the BEA income estimates. Noncorporate capital services and noncorporate hours each are assumed to receive the same percentage of corresponding factor returns as elsewhere in the industry.

Capital costs of production

Data are available from BEA for employee compensation and for corporate capital income. Corporate capital income is defined by BLS to include unadjusted before-tax profits, corporate capital consumption allowances, corporate net interest payments, corporate inventory valuation adjustments, and a portion of indirect business taxes. Corporate capital income is used to determine the corporate rental price for each type of asset. However, BEA reports only a single figure for proprietors' income, which reflects returns to both labor and capital. Since data are available on hours of self-employed, and on noncorporate capital stock, it is possible to develop an implicit capital-labor split of proprietors' income by assuming either that proprietors earn the same wage as employees or that corporate and noncorporate capital yield the same rate of return.

Unfortunately, the two methods of imputation applied together generally overestimate the NIPA measures of proprietors' income. Rather than select one imputation over the other, the two methods are initially employed simultaneously, and the results are reconciled to the BEA proprietors income estimate.

First, an imputation is made for noncorporate income by assigning self-employed and unpaid family workers the same average wage received by paid employees, and then adding to that an imputation of capital income by assigning noncorporate capital the same rental price as corporate capital. This imputation is compared to noncorporate income in the NIPA. (Noncorporate income includes proprietors' income, noncorporate capital consumption allowances, and a portion of indirect business taxes.) The imputation is adjusted to equal the reported noncorporate income by multiplying the wages of self-employed and unpaid family workers and the noncorporate rate of return by a single scalar which equates the imputed and NIPA totals.

Thus, noncorporate wages and the rate of return to capital are scaled back proportionally to determine proprietors' capital and labor shares. It should be noted that the scalar is applied only to the rate of return on capital, not to the entire rental price. Thus, the noncorporate rates of economic depreciation, asset revaluation, and indirect taxes are held equal to the corporate sector. The rationale for this treatment is that these other elements are exogenous for the self-employed. The self-employed can willingly accept lower wages and returns to their capital in exchange for the greater degree of independence—or for some other reason. However, their preference is unlikely to affect factors like economic depreciation or inflation.

Noncorporate capital services and noncorporate hours each are assumed to receive the same percentage of corresponding factor returns as elsewhere in the industry. Thus, the noncorporate rate of return and proprietors' (self-employed) compensation per hour are compared to the corporate rate of return and employees compensation per hour respectively. For example, if the noncorporate rate of return is approximated as two-thirds of the return on corporate capital, proprietors' compensation per hour will also be two-thirds of employee's compensation per hour. The equation used to determine an appropriate adjustment ratio stems from the following identity:

$$(25)\ \ CUY = ECM + KRC\,(CCC) + PCM + KRN\,(CCN)$$

where,

CUY = current $ income

ECM = employee's compensation

KRC = net corporate productive capital stock

CCC = corporate rental price

PCM = proprietors' compensation

KRN = net noncorporate productive capital stock

CCN = noncorporate rental price

PHR = proprietors' hours

REM = adjustment ratio

The initial estimate of noncorporate rental price used is corporate rental price. Proprietors' compensation is initially estimated as proprietors' hours (PHR) multiplied by employee's compensation per hour (ECM/EHR).

Thus:

$$(26)\ \mathrm{PCM} = \mathrm{PHR} * (\mathrm{ECM}/\mathrm{EHR})$$

The rental prices are divided into two parts. One part includes the rate of return (*R*). The other part includes depreciation less capital gains (*D*). The noncorporate rate of return is the part of the rental price that is adjusted downward or upward by an adjustment ratio (REM). This adjustment reflects the constraint (equation 25) that current dollar income must exactly equal payments to factors. The theory is that only this portion of the rental price lies within the proprietors' control. Noncorporate depreciation and capital gains are assumed not to occur differently than in the corporate sector. Proprietors' compensation is also adjusted downward or upward by this adjustment ratio. Note that this is equivalent to saying that:

$(27)\ \mathrm{PCM}/\mathrm{PHR} = \mathrm{REM}((\mathrm{ECM}/\mathrm{EHR})$ since $\mathrm{PCM} = \mathrm{REM}(\mathrm{PHR}(\mathrm{ECM}/\mathrm{EHR}))$.

The equation used to derive the adjustment ratio is now as follows:

$$(28)\ \mathrm{CUY} = \mathrm{ECM} + \mathrm{KRC}\,(\mathrm{R}+\mathrm{D}) + \mathrm{REM}\,(\mathrm{KRN}(\mathrm{R})) + \mathrm{KRN}\,(\mathrm{D}) + \mathrm{REM}(\mathrm{PHR}(\mathrm{ECM}/\mathrm{EHR})).$$

Solving for the adjustment ratio:

$$(29)\ \mathrm{REM} = \frac{\mathrm{CUY} - \mathrm{ECM} - \mathrm{KRC}\,(R+D) - \mathrm{KRN}\,(D)}{(\mathrm{PHR}\,(\mathrm{ECM}/\mathrm{her})) + \mathrm{KRN}\,(R)}$$

In addition to this equation, we also assume an alternative hypothesis. All parts of noncorporate capital income (including depreciation less capital gains) are assumed to participate in the adjustment. This has the effect of increasing the base of the adjustment and smoothing it out. This alternative is reflected in equation (30):

$$(30)\ \mathrm{REM} = \frac{\mathrm{CUY} - \mathrm{ECM} - \mathrm{KRC}\,(R+D)}{(\mathrm{PHR}\,(\mathrm{ECM}/\mathrm{EHR})) + \mathrm{KRN}\,(R+D)}$$

Measures of real compensation per hour reflect the adjustment of hourly compensation for changes in consumer prices.

Real compensation per hour (RC) is computed as hourly compensation deflated by an index of consumer prices (CPI):

$$(31)\ Real\ Compensation = \frac{(Current\ \$\ compensation/Hours\ of\ labor\ input)}{Consumer\ price\ index}$$

The price changes for recent quarters are based on the BLS Consumer Price Index for All Urban Consumers (CPI-U). For earlier periods consumer prices are based on the BLS Consumer Price Index research series (CPI-U-RS).

Unit labor costs (ULC) are computed as labor compensation (C) per unit of output, but are often represented as follows:

$$(32)\ \ Unit\ labor\ costs = \frac{(Compensation/Hours\ of\ labor\ input)}{(Output/Hours\ of\ labor\ input)}$$

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

Unit nonlabor payments (UNLP) include the nonlabor components of value added in a given sector—consumption of fixed capital, taxes on production and imports less subsidies, net interest and miscellaneous payments, business current transfer payments, rental income of persons, and the current surplus of government enterprises as well as profits—whereas unit nonlabor costs (UNLC) exclude profits. These measures are computed as:

$$(33)\ \ Unit\ nonlabor\ payments = \frac{(Current\ dollar\ output -\ Current\ dollar\ compensation)}{Output}$$

$$(34)\ \ Unit\ nonlabor\ costs = \frac{(Current\ \$\ output - Current\ \$\ compensation - Current\ \$\ profits)}{Output}$$

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

$$(35)\ \ Labor\ share = \frac{Current\ dollar\ compensation}{Current\ dollar\ output}$$

Analogously, the non-labor or capital share is defined as follows:

$$(36)\ \ Nonlabor\ share\ = \frac{(Current\ \$\ output - Compensation)}{Current\ \$\ output}$$

$$(37)\qquad\qquad = 1 - Labor\ Share$$

Presentation of data

Most of the measures are presented quarterly and annually in index form. Indexes are computed from basic data or analytic ratios by dividing the series by its own base year annual value 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:

$$(38)\ \ Q_t = 100(V_t/V_{t-1})^4 - 100$$

$$Y_t = 100(V_t/V_{t-4}) - 100$$

where,

T is a time subscript denoting the quarter,

V is a series,

Q_t is the quarterly percentage change in series *V* from quarter *t-1* to quarter *t*, measured at a compound annual rate, and

Yt is the percentage change in series *V* from quarter *t-4* (the same quarter 1 year before) to quarter *t*.

Indexes are published to three decimal points and percent changes are published to one decimal point.[14]

NOTES

[1] 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.

[2] Measures are multiplied by 52 to represent the number of weeks in a year to bring the production hours worked to an annual basis. From there, the annualized monthly estimates of production hours worked are averaged across three months to obtain a quarterly measure at an annualized rate.

[3] For the annual multifactor productivity measures, estimates of annual farm employment are derived using data from the U.S. Department of Agriculture.

[4] For additional information concerning data sources and methods of measuring labor composition, see Cindy Zoghi, “Measuring labor composition: a comparison of alternate methodologies,” *Labor in the New Economy* (University of Chicago Press, 2010), http://www.nber.org/chapters/c10834.pdf.

Also, see also *Changes in the composition of labor for BLS Multifactor Productivity measures (U.S. Bureau of Labor Statistics, March 2016), class="MsoHyperlink">https://www.bls.gov/mfp/mprlabor.pdf.*

[5] Some researchers use “potential experience,” which is constructed using age and education, instead of age.

[6] For more information, please see data at the U.S. Department of Labor’s Women’s Bureau’s “Women in the labor force,” available at https://www.dol.gov/wb/stats/stats_data.htm or the Current Population Survey at https://www.bls.gov/cps/ .

[7] The term "usual" is determined by each respondent’s own understanding of the term. If the respondent asks for a definition of "usual," interviewers are instructed to define the term as more than half the weeks worked during the past 4 or 5 months.

[8] The industry classifications are job specific, so that the main and second jobs can be in different industries for the respondent. These second jobs are moved to the appropriate industry.

[9] BLS uses the median wage rather than the mean wage because the median is less sensitive to outliers.

[10] Charles R. Hulten, “The measurement of capital” *Fifty years of economic measurement: the Jubilee of the conference on research in income and wealth* (University of Chicago Press, 1991), http://www.nber.org/chapters/c10834.pdf.

[11] Current dollar expenditures for privately financed research and development are obtained from annual issues of Research and Development in Industry published by the National Science Foundation. Further description of these data and methods can be found in BLS' *The Impact of Research and Development on Productivity Growth*, Bulletin 2331 (U.S. Bureau of Labor Statistics, September 1989).

[12] The triangle (delta) refers to discrete change with respect to time. For example, $\Delta \ln Z = \ln Z(t) - \ln Z(t-1) = \ln[Z(t) / Z(t-1)]$ *for variable Z.* The percentage change in Z is given by $[\exp(\Delta \ln Z) - 1]$ *or* $[Z(t)/Z(t-1)] - 1$.

[13] Peter B. Meyer and Michael J. Harper, "Preliminary estimates of multifactor productivity growth," *Monthly Labor Review* (June 2005), pp. 32–43, https://www.bls.gov/opub/mlr/2005/06/art3full.pdf.

[14] The index numbers and rates of change reported by BLS for productivity and costs in its news release are rounded to one decimal place. All percent changes in the release are calculated using index numbers to three decimal places. These index numbers to three decimal places are available at https://www.bls.gov/data/home.htm, or by contacting the BLS Division of Major Sector Productivity.

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Presentation

Indexes of output per hour, compensation per hour, and related cost data are published twice each quarter in the Bureau of Labor Statistics news release, Productivity and Costs(LPC). This usually occurs 1 week following the Advance and Second Estimate of the Bureau of Economic Analysis (BEA) Gross Domestic Product release. News releases and historical datasets can be accessed online by visiting the Labor Productivity and Costs website at https://www.bls.gov/lpc.

News releases, data tables, documentation, and other publications can be accessed at https://www.bls.gov/lpc. Data are also available in Excel tables. More detailed data are available upon request by calling (202) 691-5606 or by sending an email to productivity@bls.gov. Information on "Productivity and Costs" news releases is available to sensory-impaired individuals upon request. Voice phone: 202-691-5200; Federal Relay Service number: 1-800-877-8339.

Multifactor productivity measures are announced each year in the news release, Multifactor Productivity Trends. Comprehensive tables can be downloaded at www.bls.gov/mfp/mprdload.htm. More detailed data are available upon request by calling (202) 691-5606 or by sending an email to MFPweb@bls.gov.

Included are annual indexes of multifactor productivity, capital inputs, and related measures for the private business and private nonfarm business sectors. Manufacturing measures are announced separately on an annual basis in the news release, Multifactor Productivity Trends in Manufacturing. News releases and historical datasets can be accessed online by visiting the Multifactor Productivity website at https://www.bls.gov/mfp/.

Revisions schedule to productivity data

Productivity and cost measures are regularly revised as more complete information becomes available or, more rarely, when methods change. The labor productivity and costs measures are first published within 40 days of the close of the reference period; revisions appear 30 days later, and second revisions, after an additional 60 days. In the business sector, the third publication (second revision) of a quarterly index of output per hour of all persons has differed from the initial value—between -1.4 and 1.4 index points approximately 95 percent of the time. This interval is based on the performance of this measure between the fourth quarter of 1995 and the fourth quarter of 2019.

On an annual basis, the LPC output measures obtained from BEA are revised historically by 5 years and published in July. The BLS Office of Productivity and Technology (OPT) then folds these historical revisions of the BEA July news release into the LPC for publishing in the early August news release. Similarly, the BLS Current Employment Statistics program annually revises its historical data by 5 years, with their benchmarking revisions occurring in February. These are then incorporated into the LPC March release. As the OPT program is the secondary user of the data, OPT data are revised following revisions of its source data.

The multifactor productivity statistics are more routinely revised historically and are obtained through many more data sources—making a clear revision timeline more challenging to convey. Aside from methodological changes that occur frequently in these series, the same sources of revisions are encountered with respect to labor and BEA inputs as the LPC release outlines. In addition, when the BEA GDP by industry data accounts are historically updated, these are also incorporated at the next annual revision and these revisions can go back as far as the initial year of the series.

Errata policy

As the Labor Productivity and Costs release is a principle federal economic indicator, the errata policy is quite strict. Any significant error, encompassing more than 0.1 percentage point from the published rate of growth of labor productivity, output, or hours will constitute a significant revision at the nonfarm business level.

It is BLS and the OPT program's policy that any significant revision be immediately corrected with the utmost urgency. If the error is discovered within 2 weeks of the next release, language will be added to the next release to identify the error, however a reissue of the previous release may not occur, as the timing on reissue and the coincident release would be too close and might ultimately confuse the releases. We would, however, identify the error on the web when the extent of the error can be evaluated. It is the OPT mission to provide accurate, relevant, and honest productivity measures to help inform policy makers and decision makers about the health and direction of the U.S. economy.

Subscribe to the major sector productivity news releases on the BLS website at https://public.govdelivery.com/accounts/USDOLBLS/subscriber/new.

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History

Timeline of events

The U.S. Bureau of Labor Statistics (BLS) started releasing industry level labor productivity measures in the1800s. The following is a timeline of events that have taken place.

- 1898 BLS releases “Hand and Machine Labor,” a study of 60 manufacturing industries.
- 1920 BLS begins publishing industry indexes of labor productivity.
- 1922 the BLS fourth commissioner, Ethelbert Stewart, signed an agreement with the Babson Statistical Organization for a productivity study of the construction industry.
- 1935 BLS applies to the Works Progress Administration (WPA) for funds to conduct studies of productivity in 50 industries.
- 1940 Congress authorizes BLS to start continuing studies of productivity and technological changes.
- 1942 BLS begins a number of studies of labor requirements for defense industries related to World War II.
- 1955 BLS published labor productivity measures for manufacturing as a whole covering the 1939–55 period.
- 1959 BLS published labor productivity of the total private economy covering the 1909–58 period.
- 1976 BLS begins to publish quarterly indexes of labor productivity, compensation per hour and unit labor costs for the business, nonfarm business, manufacturing—including durable and nondurable goods producing subsectors—and nonfinancial corporations sectors.
- 1983 BLS began publishing multifactor productivity (MFP), which is also referred to as total factor productivity (TFP), for private business, private nonfarm business, and manufacturing sectors.
- 1987 BLS started publishing the multifactor productivity measures for the manufacturing sector including total, durable, and nondurable manufacturing and 20 Standard Industry Classification (SIC) manufacturing industries.
- 1989 BLS moves to an hours-worked measure instead of hours-paid measure in the major sector labor productivity program to better reflect the labor being used in production.
- 1994 BLS add the effects of research and development (R&D) spillovers to private nonfarm business MFP. BLS also begins publishing measures of labor composition for private business and private nonfarm business.
- 1995 BLS adopts the Annual chain-weighted Törnqvist indexes for measuring changes in industry output.
- 1996 BLS incorporates improved Bureau of Economic Analysis (BEA) measures of real output in the U.S. business and nonfarm business sectors based on superlative indexes in the major sector labor productivity program.
- 1998 A major industry expansion is completed, increasing labor productivity coverage from 180 industries to more than 500 industries.
- 1999 Nonmanufacturing MFP measures and detailed industry unit labor cost measures on at the National Income Product Account level are published for the first time.
- 2000 BLS expands Industry multifactor productivity measures to cover all 140 3-digit SIC manufacturing industries.
- 2003 Industry labor productivity measures are converted from the SIC system to the North American Industry Classification System (NAICS).
- In the mid-2000s, BLS productivity program conducted research into measuring the labor composition at a more detailed industry basis.

- 2005 BLS major sector productivity program starts using the BLS Current Population Survey information—that includes employment and hours worked data for the self-employed and unpaid family workers to accurately account for multiple jobholders.
- 2006 BLS publishes its 60 NIPA-industry MFP KLEMS measures based on the NAICS system for the first time.
- 2007 Industry multifactor productivity measures are converted from the SIC system to the NAICS system.
- 2008 A collaborative project between the BLS productivity program and the BEA National Accounts begins to measure productivity at the total economy level leading to produce a concordance from the national accounts measures to the BLS productivity programs measures.
- 2009 BLS publishes measures of employment and hours of all persons for all 3- and 4-digit industries. Also in the same year, it introduces a total economy measure of MFP.
- 2014 Industry labor measures are published as hours worked instead of hours paid.
- 2015 BLS includes intellectual property products in the asset composition for private business, private nonfarm business, and the detailed industries in order to align capital services with BEA value-added output.
- 2016 Labor composition for the 60 NIPA-industries encompassing the private business sector was added.

2017 BLS improves major sector productivity measures by incorporating a new methodology for calculating the hours worked to hours paid adjustment ratios based on detailed industry data from the BLS National Compensation Survey was introduced.

The U.S. Bureau of Labor Statistics (BLS) has produced studies of labor productivity since the 1800s. The fourth BLS commissioner Ethelbert Stewart made great strides in advancing productivity measurement when in 1922 he signed an agreement with Babson Statistical Organization for a productivity study of the construction industry. While that program was unsuccessful, Stewart brought Ewan Clague from the University of Wisconsin to lay the foundation of an industry productivity program to measure output per man-hour for the steel, automobile, shoe, and paper industries. A year later, 11 more industries were added. Clague would later go on to become the sixth BLS commissioner.[1]

By 1935, a productivity project was proposed to the Works Progress Administration (WPA) to conduct a productivity study of 50 industries. In cooperation with the WPA National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques, the Bureau conducted several labor productivity surveys. The main concern at the time was from displaced labor due to technological advances such as the telephone and automation developments in the steel industry. At the urging of unions, Congress authorized BLS to continue the labor productivity studies and devoted funds to support that effort resulting in the Productivity and Technological Development Division in 1940.

After a brief pause for World War II, productivity studies were resumed. However, the funding for surveys was cut, forcing the productivity program to rely on secondary sourcing to compile statistics. That tradition carries on today, as the productivity program entirely relies on other agencies and programs for data to measure the nation’s productivity growth. The productivity statistics in the 1950’s were a source of great debate from a labor and management perspective. The policy implications of the statistics, as well as the complexity of the measures, provided both labor and management plenty of things to debate, and that dialogue continues to this day.

Labor productivity

Labor productivity measures were published for manufacturing as a whole in 1955—covering the period from 1939 to1955. That work expanded to publication of labor productivity of the total private economy in 1959 to cover the period from 1909 to 1958.[2] The productivity measures were later extended to quarterly indexes of labor productivity, compensation per hour and unit labor costs for the business, nonfarm business, manufacturing (and its durable and nondurable goods producing subsectors) and nonfinancial corporations sectors in 1976. The primary source of labor input for productivituy measurement has always been BLS Current Employment Statistics program data on employment and paid hours of employees in nonfarm establishments. To better reflect the labor being used in production, BLS moved from using an hours-paid measure, which inaccurately captured vacation time as work time, to a more appropriate hours-worked measure in August 1989.[3]

Improvements have continued as they have become available. In 1996, the labor productivity program incorporated improved Bureau of Economic Analysis measures of real output in the U.S. business and nonfarm business sectors based on superlative indexes rather than constant dollars. The BLS Current Population Survey had long provided employment and hours worked data for the self-employed and unpaid family workers, when in June 2005 the BLS productivity program began to use information from this survey to take proper account of multiple jobholders. This improvement resulted in the entirely jobs-based employment estimate used in the labor productivity estimates.[4] Another improvement was made in 2017 when a new methodology for calculating the hours worked to hours paid adjustment ratios based on detailed industry data from the BLS National Compensation Survey was introduced.

Multifactor productivity

In 1983, BLS developed and began publishing a broader measure of productivity, multifactor productivity (MFP), which is also referred to as total factor productivity (TFP), for private business, private nonfarm business and manufacturing. These measures of MFP use capital and labor for combined inputs and were among the early statistical organizations to adopt the use of a changing weight Tornqvist superlative price index.[5]

Over the years, the BLS productivity program increased the number of MFP series measured. In 1987, BLS expanded its MFP measures to include detailed coverage of the manufacturing sector with the release of total, durable, and nondurable manufacturing and 20 Standard Industry Classification (SIC) manufacturing industries. These measures fit the growth accounting framework of KLEMSusing a sectoral output measure that includes energy, materials, and purchased services in addition to capital and labor for combined inputs.[6]

BLS first introduced nonmanufacturing industry productivity measures in 1999 and as prices and data expanded with a BLS-wide and statistical community-wide service initiative in the early 2000s, continued to improve on these measures. In 2006, BLS published its 60 industry measures on a North American Industry Classification System (NAICS) system for the first time. A total economy measure of MFP was introduced in 2009.

Improvements to the measurement of the multifactor productivity estimates were also made along the way. An improvement to measure the effects of the research and development (R&D) spillovers was made in 1994. This measure was added to private nonfarm business in 1994.[7]

In 1994, BLS also began publishing measures of labor composition for private business and private nonfarm business. In the mid-2000s, the BLS productivity program conducted research into measuring the labor composition at a more detailed industry basis.[8] In 2016, the 60 sectors encompassing the private business sector were labor composition adjusted and that adjustment was fully integrated into the private business sector labor composition measure.

As part of the 2013 National Income and Product Accounts (NIPA) comprehensive revision, BEA incorporated intellectual property products into private fixed investment (PFI) measures. Intellectual property products are comprised of software (purchases of prepackaged software and own-account software), research and development, and artistic originals. Starting in 2015, BLS now includes intellectual property products in the asset composition for private business, private nonfarm business, and the detailed industries in order to align capital services with BEA value-added output.

Collaborative studies

In 2008, a collaborative project between the BLS productivity program and the BEA National Accounts began to measure productivity at the total economy level. The first effort produced a concordance from the national accounts measures to the BLS productivity programs measures.[9] Subsequent efforts produced a 63-industry decomposition of GDP by the capital, labor, energy, material, services, and multifactor productivity measures back to 1987 and research into a historical series back to 1947 was completed, meeting the desires of many key macroeconomist stakeholders.

NOTES

[1] *First Hundred Years of the Brureau of Labor Statistics*, Bulletin 2235 (U.S. Department of Labor, September 1985), https://fraser.stlouisfed.org/files/docs/publications/bls/bls_2235_1985.pdf.

[2] Ibid, pp. 203.

[3] Mary Jablonski, Kent Kunze, and Phyllis Flohr Otto, “Hours at work: a new base for BLS productivity statistics,” *Monthly Labor Review* (February 1990), pp. 17–24.

[4] To learn more on job-based employment estimates, visit https://www.bls.gov/lpc/lprjobsnote.pdf.

[5] Edwin R. Dean, Michael J. Harper, Mark S. Sherwood, “Productivity measurement with changing weight indexes of outputs and inputs” (paper presented at the OECD Expert Workshop on Productivity: International Comparison and Measurement Issues, May 2–3, 1996), https://www.oecd.org/sti/ind/1825894.pdf.

[6] See Robert Solow, “Technical change and the aggregate production function,” *Review of Economics and Statistics,* August 1957, pp. 312–320.

[7] *The Impact of Research and Development on Productivity Growth*, Bulletin 2331 (U.S. Department of Labor, September 1989), https://www.bls.gov/mfp/research_and_development.pdf.

[8] Cindy Zoghi, “Measuring labor composition. A comparison of alternate methodologies,” in Katharine G. Abnraham, James R. Spletzer, and Michael Harper, eds, *Labor in the New Economy* (University of Chicago Press, 2010), pp. 485–91, https://www.nber.org/chapters/c10834.pdf.

[9] Dave Wasshausen, Brent Moulton, Steven Rosenthal, Michael Harper, “Integrated GDP-Productivity Accounts,” *American Economic Review,* vol. 99, no. 2, May 2009, pp. 74-79, https://www.aeaweb.org/issues/100.

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More Information

Labor productivity, costs, employment, and hours data as well as a variety of supporting documentation are available on the BLS website at https://www.bls.gov/lpc. This page includes data for both the Division of Major Sector Productivity as well as Industry Productivity Studies.

Multifactor productivity data for both industries and major sectors can be found at https://www.bls.gov/mfp.

The following are direct links to specific topics.

- Current labor productivity and costs news releases: https://www.bls.gov/lpc/news.htm
- Archived historical labor productivity and costs news releases: https://www.bls.gov/bls/news-release/prod.htm
- Labor productivity and costs tables and charts: https://www.bls.gov/lpc/tables.htm
- Current multifactor productivity news releases: https://www.bls.gov/mfp/news.htm
- Archived historical multifactor productivity news releases: https://www.bls.gov/bls/news-release/home.htm#PROD3
- Labor productivity and costs publications: https://www.bls.gov/lpc/publications.htm
- Productivity glossary: https://www.bls.gov/mfp/optglossary.htm
- Labor productivity and costs frequently asked questions: https://www.bls.gov/lpc/faqs.htm
- Multifactor productivity publications: https://www.bls.gov/mfp/publications.htm
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