Improvements to the quarterly productivity measures

The use of annually-weighted output measures for productivity calculations will eliminate a source of bias and reduce revisions

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Economists in research and public policy have given considerable attention to identifying the sources of long-term productivity growth and the relationship between productivity and wages. Productivity statistics also play an important role in short-run analysis of trends in prices and in the competitiveness of a Nation's exports.

This article discusses methodological improvements to the quarterly productivity series published by the Bureau of Labor Statistics that will improve the accuracy and usefulness of the data and reduce the size of revisions in the future.

Since 1976, BLS has issued eight press releases a year presenting annual and quarterly measures of productivity, hourly compensation, and unit labor costs for business, nonfarm business, manufacturing (durable, nondurable, and total), and nonfinancial corporate sectors in the United States.

- The primary data source for output and compensation has been the national income and product accounts produced by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce;
- quarterly data on manufacturing output are based on the industrial production indexes published by the Federal Reserve System Board of Governors;
- data on employment and average weekly hours are derived primarily from the Current Employment Statistics and Current Population Survey programs of BLS; and
- establishment data are adjusted from an "hours paid" basis to an "hours worked" basis using the BLS Hours at Work Survey.

The national income and product accounts include aggregate measures of gross domestic product (GDP) in current and constant prices. Several components of constant-dollar GDP are subtracted from total constant-dollar GDP to derive the measure of business sector output used by BLS to compute its productivity series. The components subtracted are: the product of general government, private households, and nonprofit institutions; the rental value of owner-occupied dwellings; and the statistical discrepancy. Nonfarm business output further excludes farm output.

BLS measures of manufacturing output (and its durable and nondurable components) are based on annual measures of constant-dollar gross product originating in manufacturing, published by BEA. Quarterly rates of change in manufacturing are computed using the industrial production indexes.

The BLS measure of the output of nonfinancial corporations is precisely the measure of constant-dollar GDP of nonfinancial corporate business, published by BEA.

Uses of productivity measures

Aggregate measures of output per hour worked have risen over the long term for several reasons. Among the most important sources of labor productivity change are the incorporation of

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technological improvements in production processes, increases in capital per worker, improvements in workers' skills, improvements in the efficiency of production, and increases in the proportion of output in "more productive" industries, such as electronic and other electric equipment. Over the long-term, these productivity gains have led to steady increases in buying power and, as a consequence, average living standards.

In the shorter run, productivity measures mirror the business cycle: productivity grows more slowly, or falls, during a recession and rises rapidly during a recovery. While this pattern complicates the interpretation of productivity statistics, its predictability makes quarterly productivity measures useful in explaining the relationships between short-term changes in output, employment, and average weekly hours.

Regular revisions in measures

BLS revises productivity measures when source data on output or hours are revised to incorporate more information. Estimates of hours are regularly revised when the BLS Current Employment Statistics are updated, when their seasonal factors are revised, and when information becomes available about the ratio of hours worked to hours paid. Revisions to hours, including changes to seasonal factors, are usually confined to the most recent 5 years, although historical revisions occasionally occur.

BEA revises output on a regular schedule as additional information becomes available. Recent quarters are revised regularly to reflect more complete data on inventory changes, corporate profits and tax returns. BEA makes historical revisions about every 5 years after analyzing the quinquennial censuses. The industrial production index also is regularly revised, affecting the quarterly manufacturing productivity series published by BLS.

Two other sources of output revisions have little to do with the availability of new information. The first has been regular changes in the base year—BEA has changed the base year once every 5 years—to compute "constant dollar" output measures. Changes in the base year have been a significant source of historical revisions to productivity measures. The second has been the exclusion of one particular component of GDP (statistical discrepancy) from the BLS definitions for business and nonfarm business output. This has led to revisions in quarterly productivity that are different and frequently larger than published revisions to GDP.

Summary of changes

In late 1995 or early 1996, BLS will switch to annually-weighted output indexes for computations underlying its *Productivity and Costs* news releases. This change will parallel plans by BEA to replace its constant-dollar series as the featured measure of real GDP with an annually-weighted index by the end of 1995. Also, BLS will no longer exclude the statistical discrepancy from its output measures. These changes are more fully explained in this article; in addition, the new data for the business and nonfarm business sectors are presented and compared with existing data.

Improved output indexes

BEA computes the present fixed-weighted measure of constant-dollar GDP by dividing current-dollar output data for detailed types of goods and services by corresponding price indexes. Price indexes are time series that measure price change relative to specific year. The resulting detailed measures of constant-dollar output are added to produce an aggregate measure. The constant-dollar aggregates effectively weight items based on their prices in the base year. The base year for computing constant-dollar output measures, currently 1987, has generally been moved forward every 5 years.

Aggregates of "constant dollars" are a reasonably good measure of output if the prices of various goods are fairly stable relative to one another. However, when relative prices change, constant dollars tend to place too much weight on goods or services for which relative prices have fallen and too little emphasis on items for which relative prices have risen. This is because constant-dollar aggregates effectively weight items based on their prices in the base year. The growth rate of a constant-dollar aggregate depends on which base year is used to compute it; as a result, the growth rate is subject to revision when the base year is changed. These revisions can be systematic because consumers and investors tend to buy more of those goods and services that have become relatively cheaper.

Computers have continued to be a major source of bias in the featured fixed-weighted measures. Although the prices of most goods have risen moderately, the prices of computers, adjusted for quality change, have fallen dramatically. In 1995, computer prices are much lower than in 1987, and in 1987 they were much lower than in the 1970's. Rapid growth in production of computers during the 1990's has been given too much weight in total output growth in aggregates based on constant 1987 dollars. Therefore, growth of GDP and of business and nonfarm business output have been overstated since 1987. Similarly, growth of these aggregates has been understated in earlier years. The problem is more acute for measures of manufacturing output because computers are made in that sector.

The bias in computer prices is a special case of a more general problem in constructing economic indexes: How to construct an aggregate quantity (or price) measure of two or

more components when their relative prices (or quantities) are changing. Much has been written in the economics literature about how to address this "index number problem."

While a unique formula does not exist to handle all sets of data perfectly, a family of formulas and techniques has been shown to approximate the precise solution very closely. Any of these techniques avoids the most important sources of systematic bias embodied in the constant-dollar method.

The improved techniques involve the use of Fisher Ideal or Tornqvist index number formulas, which are examples of "superlative" index number formulas, to compute aggregate output between pairs of years. To compute time series, "chain indexes" or similar techniques are used to combine aggregate growth rates between pairs of years to create index numbers for longer time periods. BLS research, and that of other experts, show that the different improved techniques generally yield empirical results that are similar.

These improved aggregation techniques were developed in numerous scholarly books and articles. Years ago, Irving Fisher[1] of Yale University, and, more recently, Erwin Diewert[2] of the University of British Columbia and his coauthors, studied the criteria that a superlative index number should meet. Dale Jorgenson and Zvi Griliches[3] of Harvard University pioneered the use of these techniques in measuring productivity. Other scholars have further developed the theory of index numbers and the techniques of applying index numbers to specific economic problems, including the application of superlative index numbers to the measurement of trends in productivity.[4] The properties of alternative index number formulas are discussed in a technical note by Brian Sliker of the Bureau of Labor Statistics.[5]

In 1983, BLS became the first Government statistical agency to use these techniques to develop an aggregate U.S. performance measure when it introduced measures of multifactor productivity.[6] These measures divided output by an index of "combined inputs" of labor and capital. Annually chained Tornqvist indexes were used to combine *inputs* of capital and labor, and subcategories of capital. In 1993, BLS began using Tornqvist indexes to combine subclasses of labor inputs in its work estimating the effects of labor composition change on aggregate productivity.[7]

Since 1987, BLS has developed multifactor productivity measures for 19 two-digit manufacturing industries and for selected three- and four-digit industries that use Tornqvist indexes for combining *outputs* and inputs. This summer, BLS began using Tornqvist indexes to aggregate outputs for its 180 labor productivity measures for selected industries.[8]

Annually weighted output indexes

BEA examined the use of annually-weighted indexes in the calculation of national income and product account data in a series of articles in the *Survey of Current Business* beginning in 1989.[9] Since 1993, BEA has regularly published its quarterly measure of GDP based on the "chain-type annually-weighted" indexes as alternative indexes. As one of the conclusions emerging from BEA's "Mid-Decade Review," BEA recently announced its planned replacement of the fixed-weighted index as its featured measure with a chain-type index.[10]

BEA and BLS have designed specifications for output measures that are suitable for various BLS publications about major sector productivity. In July 1994, BLS published *annual* multifactor productivity measures that used chain-type annually-weighted indexes of *output* produced by BEA. Since December 1994, BEA has been preparing *quarterly* measures of output for business and nonfarm business for BLS in a time frame nearly suitable for use in quarterly *Productivity and Cost* news releases published by BLS.

BLS soon will be using annually-weighted indexes of output in all of its quarterly and annual measures of output per hour and unit labor costs. BEA will compute quarterly data for business and nonfarm business for BLS using the same conventions it uses to compute quarterly GDP in its chain-type annually-weighted indexes. Starting with its chain-type measure of real GDP, BEA will remove those GDP components that BLS excludes from its definitions of the business and nonfarm business sectors.

An annually-weighted index for nonfinancial corporate output is not yet available. BEA is considering the best way to construct this series. It is possible that BLS will temporarily discontinue its nonfinancial corporate productivity series pending completion of this work. When and if this improved series is available, BLS will use it for measuring productivity and costs.

BLS currently uses two data sources for its output series on manufacturing and durable and nondurable manufacturing. The source of the annual series is the 1987 constant-dollar national income and product account manufacturing data, based on a value-added (strictly, gross product originating) concept. This source provides manufacturing data from 1977 to the most recent year for which the data are available. As noted earlier, quarterly data on manufacturing output are based on the industrial production indexes published by the Federal Reserve Board. The industrial production data also are used to extend the manufacturing series forward from the most recent year for which the national income and product account data are available; this means, in practice, that the production data provide the annual output data for approximately the most recent 2 years.

When BLS switches to annually-weighted national income and product account data for the business and nonfarm business sectors, changes also will be made in the manufacturing output data. The new series will be prepared using a superlative index number method. BLS is studying several

sources of manufacturing data that use such a method; most of these sources are described in a recent article in the *Monthly Labor Review*.[11] The use of annually-weighted output measures, in place of constant-dollar measures, is particularly important in manufacturing, where computers are produced. When this change is made, it may prove possible to provide data for years before 1977. The quarterly output movements and the extensions of the data forward from the most recent annual data will continue to be based on the industrial production indexes.

Statistical discrepancy

As mentioned earlier, BEA provides the data for GDP and its components that BLS uses to compute productivity. Working with *nominal*, or expenditures, data, the "statistical discrepancy" and other items are subtracted from nominal GDP to arrive at business sector output. Subtraction of the statistical discrepancy has had the effect of placing the BLS measures of output on the "income side" of the GDP estimates rather than the "product side." In *nominal terms*, the product side adds up values of goods and services, while the income side adds up the disposition of the income generated by production in the form of wages, salaries, supplements, profits, net interest, and business taxes. In theory, the nominal income and product sides are equal; in practice they differ because they are measured, in large part, from different sources. Finally, the nominal data are converted to constant-dollar data, with a deflated number for statistical discrepancy forming the difference between product side and income side constant-dollar business sector output.

The difference between product side and income side business sector output has been negligible over the long run. However, this difference has been significant over shorter time spans.

When BLS changes its output data from constant-dollar output to an annually weighted index for the business and nonfarm business sectors, it also will no longer remove the statistical discrepancy. This decision is based on conceptual and practical considerations.

The concept of productivity is to compare the outputs of production with the inputs used to create them. These outputs are the goods and services that are directly measured on the product side. The costs associated with the inputs are measured on the income side. Up until now, an income side output measure has been used because it is *statistically more closely related* to labor costs. However, the product side output measure is *conceptually more closely related* to what the economy produces.

Also, BLS has determined that the income side definition has led to larger revisions of BLS productivity measures between the "preliminary" and "revised" press releases than would a product side definition. This is because BEA's source data on the income side are incomplete at the time the GDP statistics are first issued each quarter. BLS has, in effect, used a product side measure of output growth in its first press release of each quarter, and then an income side definition at the time of the second press release.

Effects of the changes

Table 1 presents comparisons of productivity trends calculated with the new methods with the trends as they have been published. Measures are compared for the business and nonfarm business sectors. Measures for these two sectors that use the new methods are not yet available for the period 1947 to 1958. Data for these years may be available from BEA in the near future.

Table 1 shows that revisions to output growth rates for the periods before 1990 will be upward. Growth rates for business and nonfarm business will be revised downward for the period 1990 to 1994.

In table 2, compound annual rates of growth of the currently published BLS output measure (a) is compared with rates of growth of the improved measure (b). The published measure is based on constant 1987 dollars and the income side of national income and product accounts. The improved measure is based on an annually chained Fisher Ideal Index and the product side. Columns (c) and (e) make the corresponding comparison for productivity growth. Column (d) shows the growth rate of a measure of productivity based on constant 1987 dollars and on the product side of the product accounts. This allows the computation of column (f), which illustrates how much the measures would be affected if BLS were to shift from the income side of the product accounts to

Table 1. Output per hour, business and nonfarm business sectors. Compound average annual rates of growth, in percent

Year	Annually-weighted output	Base-year weighted output
Business sector		
1959–94	2.0	1.8
1960–73	3.4	2.9
1973–79	1.2	.7
1979–90	1.1	1.0
1990–94	1.3	1.9
Nonfarm business sector		
1959–94	1.8	1.5
1960–73	3.0	2.5
1973–79	1.0	.6
1979–90	.9	.8
1990–94	1.2	1.8

Table 2. **The effects of improved measurement techniques on output and productivity**
Nonfarm business sector, compound average annual rates of change, in percent

Year	Output		Productivity			Difference (d) – (c)	Difference (e) – (c)
	Base-year weighted income side	Annually weighted product side (improved measure)	Base-year weighted income side	Base-year weighted product side	Annually weighted product side (improved measure)		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Trends:							
1960–94	3.1	3.4	1.5	1.5	1.8	0.0	0.3
1960–73	4.2	4.7	2.5	2.6	3.0	.1	.5
1973–79	2.5	2.9	.6	.7	1.0	.1	.4
1979–90	2.4	2.6	.8	.7	.9	–.1	.1
1990–94	2.7	2.1	1.8	1.6	1.2	–.2	–.6
Single years:							
1990–91	–1.0	–1.3	1.5	1.3	1.2	–.2	–.3
1991–92	2.4	2.3	2.7	2.8	2.6	.1	–.1
1992–93	4.1	3.2	1.3	1.2	.5	–.1	–.8
1993–94	5.3	4.1	1.9	1.3	.7	–.6	–1.2
Recent quarters:							
1993, 2nd quarter	4.7	2.3	.4	–1.2	–1.9	–1.6	–2.3
1993, 3rd quarter	4.9	2.8	2.9	1.9	.8	–1.0	–2.1
1993, 4th quarter	7.9	5.7	4.2	3.3	2.1	–.9	–2.1
1994, 1st quarter	5.2	3.5	1.7	.2	.1	–1.5	–1.6
1994, 2nd quarter	3.2	4.5	–1.4	–.5	–.3	.9	1.1
1994, 3rd quarter	4.3	4.2	2.7	3.0	2.5	.3	–.2
1994, 4th quarter	7.7	4.8	4.3	2.7	1.4	–1.6	–2.9
1995, 1st quarter	4.5	2.2	2.5	1.3	.2	–1.2	–2.3
1995, 2nd quarter	2.3	.5	4.8	3.8	2.9	–1.0	–1.9
Cyclical movements:							
1973, 4th quarter to 1975, 1st quarter	–5.6	–4.7	–1.5	–.5	–.6	.9	.9
1975, 1st quarter to 1980, 1st quarter	4.4	4.9	1.1	1.2	1.6	.1	.5
1980, 1st quarter to 1980, 3rd quarter	–6.1	–6.2	–1.6	–2.8	–1.7	–1.2	–.1
1980, 3rd quarter to 1981, 3rd quarter	3.8	4.3	2.0	1.9	2.4	–.1	.4
1981, 3rd quarter to 1982, 4th quarter	–2.5	–3.4	.4	–.3	–.6	–.6	–.9
1982, 4th quarter to 1990, 3rd quarter	3.8	4.1	1.0	1.1	1.2	.1	.2
1990, 3rd quarter to 1991, 1st quarter	–2.7	–3.9	1.4	.2	.2	–1.2	–1.2
1991, 1st quarter to 1995, 2nd quarter	3.8	2.9	2.2	2.0	1.4	–.3	–.8

the product side. Finally, column (g) shows the total effect of switching from the current measures to the improved measures.

The data in table 2 are grouped to permit various types of comparisons. Over the entire period 1960 to 1994, the improvements increased measured productivity growth by 0.3 percent a year (column g). However, the increase is larger before 1979, and the productivity estimates for the 1990's decrease by 0.6 percent a year. Each year since 1990 is revised downward. It is important to note that similar revisions to the growth rates of the 1990's would occur if BLS were to switch to 1992 constant dollars from 1987 constant dollars. The improved measures have the advantage that future revisions due to the change of base year will be eliminated.

The effects of the improvements on quarterly data are larger, with some quarterly growth rates revised downward between 2 percent and 3 percent, while that of one quarter is

Table 3. Output per hour, output, and unit labor costs in the U.S. business and nonfarm business sectors, 1959-94, based on annually weighted indexes

[1982=100]

Year	Business sector			Nonfarm business sector		
	Output per hour	Output	Unit labor costs	Output per hour	Output	Unit labor costs
1959	59.0	46.9	34.3	63.3	46.6	33.6
1960	59.9	47.7	35.2	63.8	47.3	34.8
1961	62.2	48.7	35.3	65.9	48.3	34.8
1962	65.2	51.9	35.2	69.0	51.6	34.6
1963	67.7	54.2	35.2	71.4	54.0	34.6
1964	71.0	57.7	35.3	74.6	57.7	34.7
1965	73.6	61.7	35.4	76.8	61.7	34.8
1966	76.7	65.8	36.3	79.5	66.0	35.6
1967	78.4	67.1	37.5	81.0	67.2	37.0
1968	81.1	70.3	39.2	83.7	70.7	38.6
1969	81.6	72.5	41.8	83.8	72.8	41.2
1970	82.9	72.3	44.3	84.8	72.6	43.6
1971	86.4	75.0	45.2	88.1	75.2	44.7
1972	89.2	79.9	46.6	91.1	80.3	46.1
1973	92.1	85.4	49.0	94.0	86.1	48.3
1974	90.6	84.2	54.7	92.4	84.8	54.0
1975	93.3	83.1	58.4	94.6	83.1	58.0
1976	96.7	88.4	61.5	97.9	88.8	60.9
1977	98.7	93.7	65.2	99.6	94.0	64.6
1978	99.4	99.0	70.4	100.6	99.7	69.7
1979	99.0	101.7	77.6	99.7	102.3	76.9
1980	98.7	100.5	86.1	99.5	101.2	85.4
1981	100.7	103.2	92.3	100.9	103.4	92.2
1982	100.0	100.0	100.0	100.0	100.0	100.0
1983	102.8	104.6	101.0	103.4	105.4	100.6
1984	105.6	113.4	102.6	105.6	113.9	102.6
1985	107.0	117.4	105.8	106.3	117.6	106.1
1986	109.7	121.2	108.3	108.9	121.5	108.7
1987	110.1	125.3	111.8	109.1	125.6	112.3
1988	111.1	130.5	115.6	110.1	131.1	116.0
1989	111.2	133.9	119.6	110.0	134.4	120.0
1990	112.2	135.1	125.4	110.6	135.4	125.9
1991	113.3	133.4	130.1	111.9	133.6	130.7
1992	116.6	136.9	132.9	114.8	136.8	133.9
1993	117.1	140.8	136.7	115.3	141.1	137.3
1994	118.2	146.8	139.2	116.1	146.9	140.0

revised upward by about 1 percent. It is important to note that much of this quarterly volatility comes from the switch from income to product side data (column f). The switch to the product side has negligible effects on longer term growth rates. Because the improved measures are on the product side, BLS expects that future revisions to its preliminary estimates of quarterly business and nonfarm business productivity will be smaller.

While these two sources of revisions will be reduced, it should be noted that some data will continue to be revised as additional information about recent years becomes available. Data also will be occasionally revised as measurement procedures are adjusted.

The bottom panel of table 2 presents comparisons over periods defined by business cycle peaks and troughs. In each pair of rows, the first row represents a peak to trough comparison, while the second row examines trough to peak.

Empirical comparisons of the new annually-weighted "sectoral output" measures with constant-dollar gross product originating and other manufacturing series were discussed in more detail earlier this year.[12]

Table 3 presents new "annually-weighted" indexes of productivity, output, and unit labor costs for business and nonfarm business. □

Footnotes

[1] Irving Fisher, *The Making of Index Numbers* (Boston, Houghton Mifflin, 1921).

[2] W. Erwin Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, May 1976, pp. 115–145.

[3] Dale W. Jorgenson and Zvi Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, July 1967, pp. 249–283.

[4] Important contributions include François Divisia, *L'Indice Monetaire et la Theorie de la Monnaie* (Paris, Societé Anonyme du Recueil Sirey, 1926); L. Törnqvist, "The Bank of Finland's Consumption Price Index." *Bank of Finland Monthly Bulletin*, 1936, pp. 1–8; Charles R. Hulten, "Divisia Index Numbers," *Econometrica*, 1973, pp. 1017–25; W. Erwin Diewert, "Functional Forms for Profit and Transformation Functions," *Journal of Economic Theory*, 1973, pp. 284–316; Douglas W. Caves, Laurits R. Christensen and W. Erwin Diewert, "The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity," *Econometrica*, November 1982, pp. 1393-1414; and Jack E. Triplett, "Economic Theory and BEA's Alternative Quantity and Price Indexes," *Survey of Current Business*, April 1992, pp. 49–52.

[5] Brian K. Sliker, "Technical Note on Index Number Formulas" (Bureau of Labor Statistics, Office of Productivity and Technology), October 1995. This note is available from the Office (202) 606-5606.

[6] These measures were first published in *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, 1983). The aggregate framework used in this work is similar to that originally proposed by Robert M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, August 1957, pp. 312–20.

[7] See *Labor Composition and U.S. Productivity Growth, 1948–90*, Bulletin 2426 (Bureau of Labor Statistics, 1993).

[8] See Kent Kunze, Mary Jablonski, and Virginia Klarquist, "BLS modernizes industry labor productivity program," *Monthly Labor Review*, July 1995.

[9] These articles by Allan H. Young, appear in the *Survey of Current Business:* "Alternative Measures of Real GNP," April 1989, pp. 27–37; "Alternative Measures of Change in Real Output and Prices," April 1992, pp. 32–48; and "Alternative Measures of Change in Real Output and Prices, Quarterly Estimates for 1959–92," March 1993, pp. 31–41.

[10] BEA's plans were explained in "Mid-Decade Strategic Review of BEA's Economic Accounts: Maintaining and Improving Their Performance," *Survey of Current Business*, February 1995, pp. 36–66; and its update published in," *Survey of Current Business*, April 1995, pp. 48–56.

[11] William Gullickson, "Measurement of productivity growth in U.S. manufacturing," *Monthly Labor Review*, July 1995, pp. 13–28.

[12] Gullickson, "Measurement of productivity growth."