Possible measurement bias in aggregate productivity growth

By examining industry multifactor productivity in more detail, researchers can gain new insights into the hypothesis of measurement bias in aggregate output and productivity

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Output per hour in the business sector has grown about 1 percent per year since the late 1970s, according to data published by the Bureau of Labor Statistics. Some scholars in the productivity research field have suggested, however, that productivity might have grown faster.

One line of reasoning that supports this faster growth theory hinges on the decomposition of productivity trends by industry. When business sector output and hours are allocated to manufacturing and nonmanufacturing, the nonmanufacturing trend in output per hour appears to be very low. When output and hours are further allocated by industry, some of the resulting productivity trends appear to be negative. These trends are difficult to reconcile with anecdotal evidence of productivity improvements.

This article sheds some new light on these issues by using measures of multifactor productivity. The multifactor productivity framework is well suited to sorting out many of the issues because it allows us to account for capital inputs and for intermediate flows between industries. With these measures, we can compare industry and sectoral productivity trends.

The multifactor productivity measures that we present in this article are derived from various published and unpublished government data sources. Using these measures, we are able to conduct two main data exercises—one which examines aggregate manufacturing and nonmanufacturing multifactor productivity and another which examines nonmanufacturing multifactor productivity at the level of two-digit SIC industries.[1] Many of the measures that we present are unpublished, and we do not consider them to be prototypical BLS measures. The point of our data exercises is to examine possible problems with the data.

To estimate multifactor productivity for two-digit nonmanufacturing industries, we used input-output tables and other published and unpublished data. (See the appendix, which explains how we assembled the data.) In an earlier study, we describe how an "ideal" set of data, comprised of input-output tables and price deflators, might be used to construct a set of multifactor productivity measures which were in turn consistent with the economic theory of firms.[2] In this article, we emphasize that available data actually fall short of the "ideal" in a number of respects. Nonetheless, the data come close enough in concept to the "ideal" to make the industry multifactor productivity framework a useful tool for analyzing aggregate multifactor productivity data.

An advantage of this approach is that it allows us to rule out certain sources of productivity bias. Specifically, those biases resulting from an incomplete definition of productivity and those biases resulting from an improper allocation of productivity to industries can be evaluated separately from other sources of bias. A further advantage is that multifactor productivity comes closer than output per hour to reflecting the phenomena which people usually have in mind when they think of productivity such as "technological change," "efficiency gains," "increased returns to scale" and "quality change." If there is anecdotal evidence that these phenomena have been operating with a positive influence, then we might expect multifactor productivity to have a positive trend.

Aggregate productivity measures

Manufacturing and business: divergence in productivity. From 1960 to 1973, productivity grew around 3 percent per year in each of the aggregate sectors. Since 1973, however, trends have been lower, causing the United States to experience a major "productivity *slowdown.*" (See table 1.) Nevertheless, post-1973 trends also show a major *divergence* between the trends for manufacturing and those for business and nonfarm business. Manufacturing was not affected as much by the slowdown between 1973 and 1979. By 1979–98, the divergence intensified: manufacturing productivity nearly returned to its pre-1973 growth rate, while the trends languished in the other sectors. A closer look into this period shows that while all productivity trends increased from 1994 to 1998, the divergence also intensified.

Is something wrong with this picture? Noting the output per hour divergence between manufacturing and business, some users of BLS productivity data have pointed out that *nonmanufacturing* productivity growth must be quite low. Furthermore, it has been suggested that this result stands in contrast to abundant anecdotal evidence of remarkable changes in many *nonmanufacturing* industries. BLS has never published productivity measures for the aggregate nonmanufacturing sector because of concerns about such measures. However, as some users have pointed out, the aggregate productivity measures BLS *does* publish could be biased. Some have gone even further in speculating as to the implications of these low productivity trends for other government data from which they are derived. Larry Slifman and Carol Corrado, staff members of the Board of Governors of the Federal Reserve Board system, suggest that the low trends could be a manifestation of the Consumer Price Index (CPI) bias alleged by the Boskin Commission.[3]

We can think of three categories of explanations for the divergence. One category involves problems with the aggregate output measures. Three possibilities are that: 1) the trend in nominal business output could be understated, 2) the trend in nominal manufacturing output could be overstated, even if the trend in business output is correct, and 3) the trend in real output in business outside of manufacturing could be understated due to the methods used to derive real output from nominal output. The last possibility, in turn, could be the result of overstated price index numbers, which are used to deflate most of nominal output, as Slifman and Corrado suggest. Then again, it could be the result of other methods used to estimate real output.

A second category of explanations involves input mismeasurement. The trend in labor input could be biased. While we do not suspect significant bias in the long-term aggregate hours trend, there could be an allocation problem with labor input. Some authors have pointed out that BLS is counting temporary workers and other contract laborers working in manufacturing plants as nonmanufacturing workers. Because the proportion of these workers might have increased, there could be an overstatement of the manufacturing productivity trend. More generally, we note that directly employed laborers are not the only input. The trends in output per hour may reflect temporary and contract labor, changes in workers' skills, or changes in capital inputs.

A third category of possible explanations represents the null hypothesis of slow aggregate growth. The aggregate data may be correct. If this were the case, we would expect that an examination of a detailed set of industry productivity trends would reveal one of two possibilities. Either productivity must be rising very slowly in *most* nonmanufacturing industries or else productivity must be declining enough in some industries to offset the gains in others. D.W. Jorgenson and Z. Griliches once suggested a scenario in which, by accounting for all of the quality change in inputs, we might explain all of output growth, leaving multifactor productivity unchanged.[4] While this idea might still be plausible, more recent work by Jorgenson, Gollop, and B. M. Fraumeni did find multifactor productivity growth in many industries, while Griliches has concluded that productivity trends are understated due to measurement problems.[5] There is one scenario in which economic theory predicts that an industry's productivity would decline substantially for an extended period. This would occur if demand for an industry's product declines, resulting in underutilized capacity.[6] Other explanations of slow productivity have been advanced, such as J. Madrick's suggestion that the increased specialization of products requires production processes that are more labor intensive.[7] If an explanation of slow productivity growth such as this is correct, it might imply that we are missing a form of quality change, associ-

Table 1. Trends in output per hour for major sectors, compounded annual rates of change, selected periods, 1949–98

[In percent]

Year	Business	Nonfarm business	Manufacturing
1949–98	2.3	2.0	2.7
1949–60	3.3	2.6	2.0
1960–73	3.3	3.0	3.0
1973–79	1.3	1.1	2.1
1979–98	1.3	1.1	3.1
1979–90	1.2	1.0	2.6
1990–94	1.2	1.1	3.2
1994–98	1.7	1.6	4.3

ated with the diversity of new products. This would best be classified as an output measurement problem.

This article introduces additional evidence illustrating the plausibility of some of the explanations on output per hour divergence. It provides background information on how aggregate multifactor productivity data can help us to evaluate the possibilities. It examines aggregate multifactor productivity data, and then disaggregates the data by industry to find the effects on multifactor productivity trends.

Earlier BLS work

For many years, the BLS productivity program has worked to increase the conformity of its productivity measures with principles emerging from the economic literature on output, productivity, and prices. The divergence between manufacturing and nonfarm business productivity was recognized and investigated by BLS researchers in the late 1970s.[8] This research used the "multifactor productivity" concept, defined as the ratio of output to "combined labor and capital inputs." The notion of multifactor productivity, also known as total factor productivity, was grounded in economic theory by Robert Solow.[9] Starting with a production function, which included a time variable, Solow derived a measure of technological change. Solow derived a formula for multifactor productivity after assuming competitive input markets and constant returns to scale in production. By grounding the multifactor productivity measure in economic theory, Solow created a situation in which it is clear what the intended interpretation of productivity is (shifts in technology) and what conditions must hold for this interpretation to apply.[10] The BLS research led to the publication of multifactor productivity measures in 1983.[11] By including measures of capital in the denominator, BLS was able to isolate the role of capital in determining the trend in output per hour. A recent extension to the multifactor productivity work[12] has allowed BLS to isolate the effects of changes in the education and experience of the labor force on productivity. Having separated these influences, the multifactor productivity trend is a better indicator of "technological change" than is output per hour.

The 1983 measures of multifactor productivity were the first regularly published U.S. Government economic series to be formulated, in part, using a "superlative index number formula." One such formula, known as the Törnqvist, was used to aggregate inputs of labor and capital, and also detailed types of capital.[13] W. E. Diewert , who coined the term "superlative," defined this special class of index number formulas as those which are consistent with "flexible" specifications of the production function.[14] Superlative indexes are useful in creating aggregates of several price or quantity trends between two time periods. Superlative formulas incorporate information on weights from both the first and second periods being compared in an "even-handed" way.[15]

Business output measure. The source of the real output measures for the BLS business and nonfarm business productivity measures is the national income and product accounts (national accounts), produced by the Bureau of Economic Analysis of the U.S. Department of Commerce. The national accounts measures of total gross domestic product (GDP) and measures of GDP in large sectors (such as business and nonfarm business) are based on deflated expenditures on "final" goods and services. Expenditures on intermediate inputs of materials and services are excluded. The national accounts measures of real product for business and nonfarm business, which BLS uses in its productivity work (and which BLS calls "output"), are also derived from the data on deflated final expenditures.

In 1996, the Bureau of Economic Analysis introduced a measure of GDP based on a superlative index number formula (specifically, the Fisher Ideal Index). BLS has incorporated these measures of output for business and nonfarm business into its published labor and multifactor productivity measures.

Gross product originating by industry. The national accounts also include estimates of the "gross product originating" (GPO) in each industry at about the two-digit SIC level. Until 1996, BLS based its annual measures of the trend in manufacturing output on real GPO. Nominal GPO is measured using data from the income side of the national accounts. An industry's GPO equals the income earned by its primary factors of production, that is, labor and capital. Through accounting identities, GPO also represents the difference between the value of the industry's "gross output"[16] and the value of its purchased intermediate inputs. The notion of GPO is similar to the notion of "value added" (though not equivalent to the value-added data published by the U.S. Bureau of the Census). GPO is a "net output" measure, in the sense that purchased intermediates have been excluded.

The national accounts also estimate "real GPO." For most industries, this is measured by a process known as "double deflation": a price deflator for GPO is created, using a price index for the industry's gross output and a price index for its purchased inputs. The set of real GPO measures effectively allocates real GDP to industries.

A decade ago, Lawrence Mishel concluded that the growth of manufacturing output was overstated in the GPO series (as published at that time).[17] This work was followed by changes in procedures used by the Bureau of Economic Analysis in GPO measurement and by BLS in productivity measurement. The Bureau of Economic Analysis suspended publication of its GPO measures and conducted a major review.[18] BLS had used the GPO series as its annual measure of output for its published measures of productivity in manufacturing. BLS also had circulated (but never published) data on GPO per hour for the entire nonmanufacturing sector and for detailed nonmanufacturing sectors at about the one-digit SIC level. In 1991, BLS suspended circulation of these nonmanufacturing measures. After completing a redesign effort, the Bureau of Economic Analysis reintroduced GPO measures in 1993.[19]

BLS used the new manufacturing series as the basis for its published output per hour trends from 1993 until 1995. However, BLS did not resume use of GPO in its multifactor productivity reports and, since early 1996, BLS has not used GPO to determine the trend for its manufacturing labor productivity measure.

BLS sectoral output measures. Since 1995, BLS has instead used a "sectoral output" concept to measure manufacturing output and also other industry outputs. As we shall see, this choice is in keeping with the production theory-based approach to productivity measurement. In addition, the "sectoral output" concept will facilitate a BLS goal of having a comprehensive and consistent set of *industry and aggregate* productivity measures. To achieve this, we must have a set of definitions which properly accounts for interindustry trade.

Evsey Domar proposed definitions of outputs and inputs for sectors (or industries) engaged in intersectoral (or interindustry) trade.[20] We refer to outputs and inputs conforming with Domar's definitions as "sectoral"[21] outputs and inputs. Building on Solow's production function approach, Domar showed these definitions permit *consistent aggregation of productivity measures.*[22] Domar defined productivity as if each industry or sector were a "black box" (our terminology). Inputs include directly employed labor and capital services, and also intermediate materials and services purchased from *outside* the sector being measured. Outputs include intermediate products and services sold *outside* the sector.[23] Sales of intermediate products and services between establishments within the sector in question (intrasectoral transactions) *are excluded from both outputs and inputs*. Further information on this model is provided in the box. (See page 51.) Also, Gullickson and Harper provide a formal presentation of the sectoral concept using a complex industry model.[24] This model is the basis for some results we present in the next section. However, this section applies the model to the aggregate manufacturing and nonmanufacturing or "service" sectors.

Exhibit 1 illustrates an economy in which manufacturing and nonmanufacturing engage in intersectoral trade. Y refers to output, K refers to inputs of capital, and L refers to inputs of labor. The subscript M refers to manufacturing, S refers to nonmanufacturing (services), I refers to intersectoral sales, and D refers to sales to final demand.

Using this notation, we can examine, also in exhibit 1, Domar's definitions for outputs and inputs and compare them to definitions based on a system comparing "net" outputs (such as GPO) with primary factor inputs (capital and labor) for each sector.[25] For a "closed economy," the output definitions at the aggregate level are identical. However, as we disaggregate, they begin to differ. In terms of output, a sector's net output equals gross output minus all purchased intermediate inputs. Sectoral output, by contrast, excludes only those intermediate inputs purchased from within the sector. The intermediate inputs purchased from other sectors are included as inputs rather than being subtracted from gross output.

We note that the national accounts measures of GDP in business and nonfarm business, which BLS uses in productivity measurement, are fairly consistent with the sectoral output concept. However, the manufacturing GPO measures, which BLS no longer uses, differ significantly from sectoral output.

A set of aggregate multifactor productivity measures based on the net output framework has appealing properties which a set based on sectoral output lacks. For example, if manufacturing and nonmanufacturing productivity both grew at 1 percent, then aggregate productivity would also grow at 1 percent[26] in the net framework. This stems from the fact that nominal outputs are additive in the net framework. In the sectoral output framework, a "Domar weight" would be applied to each subsector's multifactor productivity trend before the trends were added. The Domar weight for productivity trends equals the nominal value of the subsector's output divided by the nominal value of aggregate output. It is clear from the output definitions that the sum of these weights for manufacturing and nonmanufacturing will exceed one. Therefore, if multifactor productivity (defined with sectoral concepts) were growing 1 percent in each subsector, then we would find that the aggregate multifactor productivity trend exceeded 1 percent. Thus *the multifactor productivity gains in two sectors engaged in trade will tend to augment one another*, from the perspective of the aggregate economy. This is a real effect. The productivity gains in each successive stage of production do augment one another in their contributions to the economy as a whole. However, the Domar framework sacrifices the property that "outputs are additive."

Implicit contribution of nonmanufacturing. BLS does not publish any measure of productivity for the whole nonmanufacturing sector.[27] However, since 1987, BLS has published multifactor productivity measures for manufacturing which reflect Domar's definitions (most recently by Gullickson).[28] Likewise, the national accounts measures which BLS uses in measuring private business multifactor productivity correspond closely to Domar's definitions.[29] In addition, all of the aggregate output measures now are derived using superlative aggregation. Before using "Domar weights" to compare these sectors, it is useful to examine the published BLS measures of multifactor productivity presented in table 2.

The private business multifactor productivity trend has been only a few tenths of a percent since 1979. By comparison, business sector labor productivity grew about 1 percent per year. The multifactor productivity trend reflects changes in

Relating industry productivity improvements to aggregate productivity measures

Evsey Domar developed a model which identifies the relationships among productivity measures when industries sell to one another. (See Evsey Domar, “On the Measurement of Technological Change,” *Economic Journal*, December 1961, pp. 709–29.) The contribution that each industry makes to aggregate growth depends on its own multifactor productivity growth rate, but, because the “sectoral” definitions of aggregate and industry multifactor productivity are somewhat different, the nature of the relationship deserves some discussion.

In one variant of his model, Domar defined multifactor productivity in terms of all outputs delivered to consumers *outside of* the industry or sector in question and only those outputs. Similarly, inputs only included items obtained from outside the industry or sector. Thus, input for industries include raw materials, components, and services, insofar as they are bought from other industries, as well as primary inputs of capital and labor. However, for the private business sector as a whole, inputs *exclude* all of the intermediate transactions between domestic industries that are part of the sector. This exclusion is desirable because transactions between these industries would appear identically as both outputs and inputs in the productivity ratio if not excluded. This double-counting would serve no purpose, and would obscure relative movements in inputs and outputs resulting from actual technical change. Therefore, aggregate productivity is best defined as deliveries to final users per unit of combined *K* (capital) and *L* (labor), with no consideration of inter-industry transactions in either output or input.

It is useful to state the definitions of aggregate and industry multifactor productivity mathematically:

$$D \log MFP = D\log Q - W_L D \log L - W_K D \log K. \qquad (1)$$

Here, *Q* is private business sector output, *L* is labor input and *K* is capital input. The growth rates of these variables, D log, are computed as the difference in the logarithms of the variables in successive time periods. The weights, W_L and W_K are the averages (over the two time periods) of the shares of labor and capital costs in the nominal value of private business sector output.

For industry, *z*, “*mfp*” is defined in terms of the broader set of inputs:

$$D\log mfp_z = D \log q_z - w_{lz} D \log l_z - w_{kz} D \log k_z$$
$$= w_{mez} D \log e_z - w_{mz} D \log m_z - w_{bz} D \log b_z. \qquad (2)$$

Here, q_z denotes industry output, k_z, l_z, e_z, m_z, b_z which are inputs to industry, *z*, of capital, labor, energy, materials, and business services. The *w* represents weights based on cost shares in the value of industry, *z*, production.

The complicating feature of this system of productivity accounts is that aggregate business sector outputs and inputs are not sums of their industry counterparts. Industry inputs include purchases from other industries, while business sector inputs exclude all intermediate transactions; industry outputs include deliveries to other industries, but business sector outputs include only deliveries to final demand. Therefore, aggregate multifactor productivity growth cannot be obtained as an average using any set of weights that sum to 1.

Industry and aggregate multifactor productivity growth can, however, be related using a set of ratios that sum to more than 1. In his original exposition of the “sector” methodology, Domar showed that either aggregate multifactor productivity growth (based on *K* and *L*) or subaggregate growth (based on inputs including intermediates) can be related to industry total-factor (KLEMS) measures through the ratios of *industry nominal output,* vq_i *to aggregate nominal output, VQ*. These ratios capture the relative effects, on the various multifactor productivity measures, of a single bona fide productivity advance at the industry level. Using these ratios, aggregate multifactor productivity can be related to the industry productivity trends:

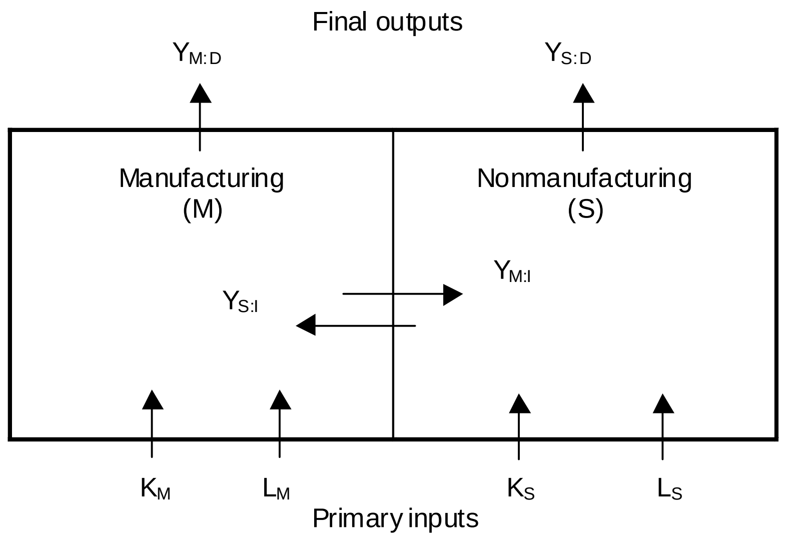
$$D \log MFP = S_i D \log mfp_i (vq_i/VQ). \qquad (3)$$

It is in this way, aggregate multifactor productivity can be attributed to a sum of contributions of constituent industries. It should be noted that one could get the identical attribution of multifactor productivity to industries by using value added weights which sum to 1 and measures of industry multifactor productivity which were defined in terms of real net output (value added) and capital and labor inputs. This attribution would be identical only if the net outputs were derived from the industry output and intermediate inputs using an algebraic equivalent to expression (2).

Also note from expression (3) that a bona fide “*mfp*” gain in any industry will affect aggregate multifactor productivity. This will be true even if the industry delivers all of its output to other industries. However, if an apparent “*mfp*” change is due to an error in measuring output, and if the output is used as intermediate input by other industries, the aggregate output and multifactor productivity trends will be unaffected. This is because the erroneous component does not enter into the aggregate computation, in expression (1). While the aggregate multifactor productivity would be unaffected, the industry attribution in expression (3) would be distorted.

Because measurement errors would affect the measures differently than bona fide productivity change, we included table 6 in the article. This table presumes that declines in industry multifactor productivity trends are due to measurement error. For table 6, the estimate of an industry’s contribution to aggregate multifactor productivity (from table 5) is reduced by the proportion of its output that is delivered to other industries.

Exhibit 1. Flows of inputs and outputs in a two-sector model of the economy



Comparison of the elements used in productivity measurement based on “sectoral” output and “net” output concepts:

	Sectoral	**Net**
“Economy” output	$Y_{M:D} + Y_{S:D}$	$Y_{M:D} + Y_{S:D}$
“Economy” input	$K_M+L_M+K_S+L_S$	$K_M+L_M+K_S+L_S$
Manufacturing output	$Y_{M:D} + Y_{M:I}$	$Y_{M:D} + Y_{M:I} - Y_{S:I}$
Manufacturing input	$K_M+L_M+Y_{S:I}$	K_M+L_M
Nonmanufacturing output	$Y_{S:D} + Y_{S:I}$	$Y_{S:D} + Y_{S:I} - Y_{M:I}$
Nonmanufacturing input	$K_S+L_S+Y_{M:I}$	K_S+L_S

output per unit of "combined labor and capital inputs." The "labor input" measures used for the private business and private nonfarm business multifactor productivity measures are hours adjusted for the effects of labor composition change. So the difference between business output per hour (table 1) and private business[30] multifactor productivity (table 2) reflects the effects of increases in capital per worker and also the effects of labor composition change.

The manufacturing multifactor productivity trends since 1979 also have been substantially lower than the labor productivity trends. The same manufacturing output measure, a sectoral output measure, is used in both tables 1 and 2. However, there are a number of differences on the input side, which account for the relatively lower multifactor productivity trends. For table 2, intermediate inputs as well as capital inputs are included along with labor inputs. On the other hand, labor input for manufacturing is measured as hours at worked in both tables 1 and 2. BLS does not publish an estimate of the effects of labor composition change for manufacturing.

In the discussion of table 1, we noted a divergence in output per hour since the 1970s, when comparing manufacturing with the larger aggregates. A divergence is also evident in the respective multifactor productivity trends in table 2. One possible explanation for the divergence in output per hour is that manufacturers might have made increasing use of workers who were employed by service firms. The hours of these workers, which are growing rapidly, show up as inputs to the service sector instead of inputs to manufacturing. If we were to consider this a misclassification, we would report service output per hour trends which were too low and manufacturing trends which were too high. However, this divergence remains in the multifactor productivity trends even though the manufacturing inputs reflect an estimate of service inputs purchased by manufacturers. Our estimate of service inputs is drawn from data on the nominal value of these inputs drawn from input-output tables and does not involve measuring the hours of service workers. These values are deflated using available price indexes that have been matched to the various types of service.[31] In principle, the service inputs include contract business services such as legal and accounting services, the value of the services of workers hired through temporary help agencies and the services of capital goods rented by manufacturing establishments. While recognizing that these data have limitations, it is interesting to compare the trend in the hours of workers employed by manufacturing plants to the trend in combined labor and purchased intermediate inputs.[32] The combined inputs grow about 1.0 percent faster than do labor hours for 1979–96. This may be compared to a 1.7-percent divergence in output per hour between manufacturing and business over the same period. Thus, using a multifactor productivity framework and the (limited) data on service inputs, we can explain only a little over one-half of the divergence in output per hour trends. While hours of temporary workers are classified in services, they represent only one of many items in our service-input measure. Therefore, it is unclear how much, if any, of the 1.0-percent is attributed to increased use of temporary workers in manufacturing.

Table 2. Multifactor productivity trends in aggregate sectors, selected periods, 1949–96

(In percent)

Year	Private business	Nonfarm business	Manufacturing
1949–1996	1.2	1.1	1.2
1949–73	2.1	1.9	1.5
1973–79	.6	.4	–.4
1979–90	.2	.0	1.0
1990–96	.3	.2	1.9

Even though our manufacturing measures reflect service inputs, a divergence remains between the manufacturing and private business multifactor productivity trends. (See table 2.) This divergence is 0.8 percent per year from 1979–1990 and 1.6 percent from 1990–1996. The divergence is affected by the fact that private business labor inputs reflect labor composition effects while manufacturing inputs do not. Table 3 shows the effects (column 3) of removing the labor composition effects (column 2) from private business multifactor productivity (column 1). We then use Domar weights to estimate the manufacturing multifactor productivity "contribution" (column 5) to the resulting "unadjusted" (for the labor composition effects) private business multifactor productivity trend (column 3). The difference between the unadjusted multifactor productivity trend and the manufacturing contribution is an estimate of the implicit contribution of nonmanufacturing (column 6) to the unadjusted multifactor productivity trend.

Since 1979, the implicit contribution of nonmanufacturing multifactor productivity has been zero. Furthermore, labor composition effects in private business were quite strong during these periods. We do not have separate estimates of these effects in manufacturing and nonmanufacturing. However, if we assume these effects were equal in the two sectors, we would conclude that the nonmanufacturing contribution has been slightly negative since 1979. *Thus manufacturing multifactor productivity more or less accounts for all of the measured multifactor productivity change in private business since 1979.*

Implications for industry productivity

It would be useful to consider, in more detail, what methods are used to construct the productivity data. This would put us in a better position to consider what accounts for the slow growth in nonmanufacturing multifactor productivity. Also, it might be useful to estimate nonmanufacturing productivity trends for more detailed industries because production occurs in firms, and because the government statistical agencies tabulate most of the relevant data by industry.

BLS has published relatively few measures for nonmanufacturing sectors or industries. This circumstance stems largely from concerns about the limitations of real output measures, which could be created from available data on nonmanufacturing industries. Nevertheless, we know that there must be some set of nonmanufacturing industry multifactor productivity trends that account for the aggregate business sector trends. To fill this void, we have engaged in an effort to estimate a set of industry multifactor productivity measures, which is implied by the measurement systems that BLS uses to create its published aggregates. We have prepared, for this article, estimates of multifactor productivity trends for nonmanufacturing industries at the two-digit level. Our approach is to use a measurement framework, which has emerged in the productivity literature in recent decades,[33] and to implement that framework using various published and unpublished government datasets (described in the appendix). The framework and data are constructed to ensure that we account for the published aggregate multifactor productivity trends. As in our aggregate exercise (table 2), we use a framework based on production theory. This framework uses the assumptions of competitive markets for input factors and constant returns-to-scale in production. Subject to these conditions, the framework allows us to isolate some of the factors that influence the productivity trends (such as changing capital-labor ratios). We also use sources of industry data that are the same—or adjusted for compatibility with—the sources underlying the BLS business sector multifactor productivity trends. This helps ensure that observations we make about the resulting industry multifactor productivity measures can be related to the aggregate measures.

Therefore, we must introduce some data and assumptions that are not part of the aggregate measurement system we are seeking to understand. We must acknowledge that what we introduce is a source of potential bias in our industry measures, in addition to any bias inherent in the aggregate system. It is important to keep this in mind when interpreting our results. Again, we caution that we do not regard the calculated industry measures to be candidates for official publication by BLS.

Multifactor productivity measures for nonmanufacturing. A dataset was constructed containing estimates of nominal values and real trends for outputs and inputs of 35 nonmanufacturing industries. The dataset contains observations for 1947, 1992, and for those intervening years for which benchmark input-output tables have been published by the Bureau of Economic Analysis. These years correspond to quinquennial economic censuses, a major source used in constructing input-output tables. Annual data on capital and labor inputs and their costs are based on those data used in constructing the BLS private business sector multifactor productivity measures. (See the appendix for more detail on the data.) Two-digit industry detail for labor and capital are developed as part of the regular BLS procedure to account for the allocation of proprietor's income between capital and labor and for the changing *industrial composition of capital*. For the purposes of this article, we remove *the adjustment for labor composition effects,* which is applied to the aggregate hours published by BLS. This adjustment accounts for the changing education and experience of workers. We remove this because we do not have information on worker skills by industry. The measures in the Domar model reflect the effects of the reallocation of labor among industries, as valued by differences in average wages by industry. The published BLS measures of "labor composition effects" reflect aggregation of labor hours differentiated by education and experience rather than by industry.

Nominal output and intermediate inputs for quinquenial census years were developed from input-output tables, the most recent being the 1992 tables described by A. M. Lawson.[34] An industry's nominal output can be tabulated from the commodities it "makes" and its expenses on intermediate inputs can be tabulated from the commodities it "uses." In an important sense, these tables underlie the published aggregate output measures and are appropriate for determining which disaggregate set of nominal input and output values (of many possible sets) is "consistent" with the published national accounts.

Because the format of the published tables has changed in various ways over the years, the tables have been modified by BLS to make them somewhat more suitable for estimating the time trends of industry outputs and inputs. Some of these "BLS modifications" were made by the Office of Employment Pro-

Table 3. Multifactor productivity growth in the private business sector, and the contribution of labor composition effects, manufacturing growth, and nonmanufacturing growth, selected periods, 1949–96

Year	Private business multifactor productivity	Private business labor composition effects	Unadjusted private business multifactor productivity	Manufacturing multifactor productivity	Contribution to private business of—	
					Manufacturing	Nonmanufacturing
1949–1996	1.2	0.2	1.4	1.2	0.6	0.8
1949–1973	2.1	.2	2.3	1.5	.8	1.5
1973–1979	.6	.0	.6	–.4	–.2	.8
1979–1990	.2	.3	.5	1.0	.5	.0
1990–1996	.3	.5	.8	1.9	.8	.0

jections which uses the tables in projecting industrial demand for workers with various skills. The authors also have made some further modifications for this article mainly to improve the consistency of the earlier tables with current input-output concepts. Both the Employment Projections staff (for the purposes of its projection model) and the authors (for present purposes) have tried to conform the input-output tables to the 1987 SIC. Adjustments to older data have been made to conform them with the 1987 SIC changes. BLS has made adjustments to remove some of the "industrial reclassifications" made in the Bureau of Economic Analysis tables which affect mainly trade and construction.

BLS output based trends, 1977–92. In addition to the input-output tables, the Employment Projections staff provides us with prices and annual values of production for industries at the two-digit SIC level of industrial detail. They currently maintain values of production and prices, covering 1972 to the present period. We have supplemented these with previous versions of these data, extending back to 1947. Thus several versions of the production and price work from the Employment Projections staff form the basis of the output measures which we have labeled "BLS output based."

Because the values of production from the Employment Projections Office are part of the process by which the input-output based growth model is constructed, they are compiled with a view toward consistency with the Bureau of Economic Analysis input-output tables and with the national accounts, in general. Whenever possible, values of production reported by the Employment Projections Office are based on data taken from the national accounts. However, because the published national accounts contain only sales to final customers ($C+I+G+X–M$), they provide the basis for total industry output only for cases in which the bulk of an industry's output is sold to final users. Examples are construction and health services. For other industries, industry outputs are based on other available sources, especially the industrial censuses and annual surveys and the Producer Price Index (PPI).

Bureau of Economic Analysis output based trends, 1977–92. As an alternative to the output trends produced by the Employment Projections staff for 1977–92, we have estimated a second set of multifactor productivity trends for this time period. For output in this alternative, we use trends in gross output developed by the Bureau of Economic Analysis.[35] The Bureau uses these in developing their GPO estimates. The Bureau of Economic Analysis has recently published industry gross output time series for 1977–96 as part of its GPO by industry program.[36] As previously mentioned, their real GPO is obtained by a process called double deflation in which real intermediate inputs are deducted from deflated gross output. The Bureau makes all of the underlying data available upon request. Since we are investigating movements in the national accounts aggregates, it benefits us to use as much data from the national accounts as possible, including the industry gross output measures on which the industry multifactor productivity estimates are based. However, mainly because the gross outputs are available only after 1977 from the Bureau of Economic Analysis, the BLS industry output data we have used in this article are similar series constructed independently by the Office of Employment Projections and provided on an unpublished basis. We have estimated an alternative set of multifactor productivity trends based on the gross output measures from the Bureau of Economic Analysis by adjusting the multifactor productivity trends derived from the data produced by the Employment Projections staff.

To estimate the Bureau of Economic Analysis output based multifactor productivity trends, we calculated adjustment factors for the BLS output based multifactor productivity trends to create a new set of such trends, which are consistent with the gross output trends from the Bureau of Economic Analysis, and inputs, which have been "adjusted for consistency." By this, we mean the adjustments effectively preserve the identities between the total outputs reported by the Bureau of Economic Analysis and the sum of outputs to other industries and to final demand. We discuss the adjustment factors we have developed further in the appendix. While use of these factors represents a tedious methodology, we present these results because the output trends from the Bureau of Economic Analysis differ significantly from the employment projections output trends for some industries.

Nonmanufacturing industry multifactor productivity trends. Table 4 presents our estimates of average multifactor productivity growth rates for industries within the U.S. private business sector. The nonmanufacturing industry measures are shown at two levels of detail—the (roughly) two-digit SIC level at which the estimates are made, and broader measures for industrial divisions. The two-digit industry estimates are based on detailed input-output tables, which are available only back to 1963; 1947–63 growth rates for broader sectors are based on less detailed tables. The early and later periods are organized around the year 1977, rather than the usual 1979 for comparisons of early and late growth trends, because a benchmark input-output table, the only systematic source of intermediate input information (discussed earlier), is available for 1977, but not for 1979.

During the 1947–63 period, all of the one-digit multifactor productivity trends were positive and most were between 1.2 and 3.5 percent. Most of the trends weakened during the 1963–77 period, but only three turned negative. During the 1977–92 period, most of the one-digit trends weakened further.

There are two sets of multifactor productivity estimates for 1977–92; one based on industry output series from the

Table 4. Estimates of multifactor productivity trends in industries, from main sources of output estimates, selected periods, 1947–92

[Compounded annual rates]

SIC	Industry	Bureau of Labor Statistics			Bureau of Economic Analysis
		1947–63	1963–77	1977–92	1977–92
1, 2	Farms	2.1	0.8	1.8	1.7
10–14	Mining	.7	–1.1	–1.2	–1.5
10	Metal mining	–	–1.6	2.3	2.0
11, 12	Coal mining	–	–2.2	2.2	1.5
13	Oil and gas extraction	–	–.9	–2.3	–2.7
14	Nonmetallic minerals, excluding fuels	–	.5	.5	.9
15–17	Construction	1.2	–.7	–.4	–.9
20–39	Manufacturing	.8	.6	.5	.7
24, 25 32–39	Durable manufacturing	.6	.8	.7	.8
20–23, 26–31	Nondurable manufacturing	1.0	.5	.2	.5
40–47	Transportation	1.4	1.9	.4	.2
40	Railroad transportation	–	2.2	2.4	5.2
41	Local and interurban passenger transit	–	2.6	–.3	.2
42	Trucking and warehousing	–	1.1	.7	–.3
44	Water transportation	–	2.5	.3	.2
45	Transportation by air	–	2.2	–1.2	–1.4
46	Pipelines, excluding natural gas	–	1.5	–.5	.2
47	Transportation services	–	.0	.9	.3
48	Communications	3.2	2.4	.4	.9
49	Electric, gas, and sanitary services	3.5	.4	–.3	–1.1
50–59	Trade	1.6	2.1	1.1	1.2
50, 51	Wholesale trade	–	2.6	2.1	1.0
52–59	Retail trade	–	1.7	.3	1.2
60–67	Finance, insurance, and real estate	.9	.7	–1.2	–1.3
60, 61, 67	Credit agencies, holding companies	–	.5	–1.9	–2.3
62	Security, commodity brokers	–	.1	1.0	.8
63	Insurance carriers	–	1.2	–3.0	–2.1
64	Insurance agents, brokers, and services	–	3.2	–3.4	–2.2
65, 66	Real estate	–	.4	– .1	– .4
7–9, 70–89	Services	.3	.2	.1	.2
7–9	Agricultural services, forestry, fishing	–	1.3	1.4	1.5
70	Hotels and other lodging places	–	1.5	–3.5	– .1
72	Personal services	–	2.3	.7	.0
73, 76	Business and miscellaneous repair services	–	.7	.3	.0
75	Auto repair, services, and garages	–	–1.1	–1.4	.5
78	Motion pictures	–	–1.2	.3	1.7
79	Amusement and recreation services	–	–.1	–.3	1.7
80	Health services	–	–1.4	–.5	– .7
81,83–89	Legal and other professional services	–	1.3	1.7	1.3
82	Educational services	–	–1.2	1.2	2.2

Bureau of Economic Analysis and one from BLS. At the one-digit level, the respective trends differ by more than 0.5 percent for only one industry, utilities (SIC 49), for which the BLS trend is greater (less negative in this case). However, more differences of this size crop up at the two-digit level. The BLS output based trend in multifactor productivity exceeds the Bureau of Economic Analysis output based trend by more than 0.5 for coal mining, trucking, transportation services, wholesale trade, and personal services. By the same criterion, the Bureau of Economic Analysis output based trends are greater for railroads, pipelines, retail trade, the insurance industries, hotels, auto repair, motion pictures, other amusements, and education. We will not attempt to explain the differences, nor determine which set of multifactor productivity measures is "better." We suspect the output series from the Bureau of Economic Analysis are more solidly controlled to industry data sources and are preferable. However, we do not have a set of input-output tables consistent with their output data. We have had to adjust the input data for consistency with outputs to estimate inputs for the Bureau of Economic Analysis output based estimates and so in this sense, the BLS output based estimates may be preferable. Rather than render judgment, as to which approach is better, we have calculated our results from both datasets.

We find multifactor productivity for the service sector *proper* (SIC's 7–9, 70–89) to be about unchanged during the 1977–92 period in both datasets. At the two-digit industry level within the service sector, multifactor productivity trends are negative for most industries for either the 1963–77 period, the 1977–92 period, or both. In some of these industries, such as hotels and auto repair, output is deflated using CPI components.

In addition to the narrowly defined services, however, there are some other notable negative multifactor productivity trends. The data for construction and for oil and gas extraction indicate that multifactor productivity declined during the 1963–77 period as well as during the 1977–1992 period; and, in both datasets, multifactor productivity declined substantially for air transportation, for credit agencies (banks), and for the insurance industries during the period from 1977 to 1992.

Consistency of industry and business sector multifactor productivity trends. Before we consider the possible interpretations of these results, we want to address the following question: How important are the effects of each of these industry multifactor productivity trends on the trend in private business sector productivity? Some of the industries illustrated in table 4 are quite small. Some, such as health services are small and have relatively little impact on the private business sector because they are operated by government agencies or by nonprofit institutions, both of which are excluded from the business sector and from our two-digit estimates. Also, we note that government enterprises are excluded from the industry measures and from the private business sector, for which BLS produces multifactor productivity measures. We want to avoid drawing broad conclusions about the business sector measures from industry multifactor productivity trends that have little effect on the aggregate.

Table 5 presents estimates of the "contributions" of industries' multifactor productivity trends to private business sector multifactor productivity. The contributions are the industry multifactor productivity trends multiplied by the industry "Domar weights." The Domar weight is the ratio of the value of the industry's sectoral output to the value of the sectoral output of the private business sector. (See the box on page 51.) Application of these Domar weights not only scales the industry multifactor productivity estimates by their relative importance, but it also permits their reconciliation with the published BLS aggregate series. To make the table easier to read, we have rounded the contributions to the nearest 0.1 (the same precision displayed in table 3). Also, we have omitted industry contributions which round off to zero in all of the three time periods.[37]

"Total contributions," near the bottom of table 5, effectively measure private business sector multifactor productivity and has been constructed by adding up the "Domar" weighted industry contributions.[38] The total includes contributions of less than 0.05 percent from industries that do not appear on the table. At the bottom of table 5 are two lines providing alternative estimates of private business multifactor productivity trends. One line reports the "Published BLS estimates," while the final line reports "BLS estimates adjusted for compatibility with industry estimates."[39] The differences between the last line (the adjusted-published data) and the "total contributions" (derived by Domar aggregation of industries) are fairly small. We would expect these lines to correspond if fully consistent data were used. Therefore, the data and methodology used to construct the industry estimates are similar enough to the aggregate data and methodology to allow an approximate (though not precise[40]) replication of the aggregate multifactor productivity

Table 5. Estimates of private business sector multifactor productivity and estimates of its attribution to industries, from main sources of output estimates, selected periods

[Compounded annual rates]

SIC	Industry	Bureau of Labor Statistics 1947–63	Bureau of Labor Statistics 1963–77	Bureau of Labor Statistics 1977–92	Bureau of Economic Analysis 1977–92
1, 2	Farms	0.3	0.1	0.1	0.1
10–14	Mining	.0	– .1	– .1	– .1
15–17	Construction	.2	– .1	– .1	– .2
20–39	Manufacturing	.8	.6	.4	.6
24, 25 32–39	Durable manufacturing	.3	.4	.3	.4
20–23, 26–31	Nondurable manufacturing	.5	.2	.1	.2
40–47	Transportation	.1	.2	.0	.0
48	Communications	.1	.1	.0	.0
49	Electric, gas, and sanitary services	.1	.0	.0	– .1
50–59	Trade	.5	.7	.4	.4
50, 51	Wholesale trade	–	.3	.3	.2
52–59	Retail trade	–	.3	.1	.3
60–67	Finance, insurance, and real estate	.1	.1	– .3	– .3
60, 61, 67	Credit agencies, holding companies	–	.0	– .1	– .1
63	Insurance carriers	–	.0	– .1	– .1
64	Insurance agents and brokers	–	.0	– .1	– .1
65–66	Real estate	–	.0	.0	– .1
7–9, 70–89	Services	.0	.0	.0	.0
70	Hotels and other lodging places	–	.0	–.1	.0
72	Personal services	–	.1	.0	.0
80	Health services	–	–.1	.0	–.1
81,83–89	Legal and other professional services	–	.1	.1	.1
...	Total contributions: Private business trend derived by "Domar" aggregation	2.2	1.6	.2	.2
...	Private business sector multifactor productivity trend estimate (compounded annual rates of change): Published BLS estimates	2.2	1.8	.2	...
...	BLS estimates adjusted for compatibility with industry estimates	2.2	1.8	.4	...

NOTE: Industries and sectors with absolute contributions rounding to less than 0.1 percent in each period are omitted from this table.
Dashes indicate data were not available.

trends from the industry multifactor productivity trends via the Domar framework.

Prior to 1963, there were no negative contributions to multifactor productivity, and during the 1963–77 period, three industry groups—mining, construction, and health services—made negative contributions of at least –0.1 percent. For 1977—92, five two-digit industries made negative contributions to the aggregate multifactor productivity trend of 0.1 percent per year or more in both datasets: mining, construction, banks, insurance carriers, and insurance brokers. (In addition, hotels contributed about –0.1 to the BLS output based estimate and utilities and health services each contributed about –0.1 to the BEA output based estimate.) Altogether, these industries with negative (measured) average multifactor productivity growth rates contributed –0.6 percent and –0.8 percent to the aggregate multifactor productivity change for 1977–92 in the datasets of BLS and the Bureau of Economic Analysis respectively.

Comparison with other results. Larry Slifman and Carol Corrado examined data on trends in labor productivity by industry.[41] In this work, they measured output with GPO. They found negative output per hour trends for most industries within the service sector proper (SIC 70–89) and indicated skepticism about these results. They suggested that output price measurement error is the "likely statistical explanation for the implausible productivity." They also did an exercise, which they called a "benchmark thought experiment," in which they "raised" the productivity trend to zero for industries that were observed to be negative. This resulted in an aggregate productivity trend that is "nearly half a percentage point faster per year" than the published aggregates. Citing this research, Federal Reserve Board Chairman Alan Greenspan has suggested that the nonfarm business productivity trends published by BLS are implausibly low. He has suggested that these trends may help support the conclusion of the Boskin Commission that the growth of the Consumer Price Index (CPI) is overstated.

There are similarities and differences between our results and the Slifman-Corrado results. We found negative multifactor productivity in many industries within the service sector proper, during the 1977–92 period (table 4). This corresponds, roughly, to one key finding of Slifman-Corrado. However, we estimate that the most important negative multifactor productivity contributions (table 5) after 1977 were from nonmanufacturing industries *outside of the service sector proper*. At the one-digit level, the finance, insurance, and real estate sector made a contribution of –0.3 percent, while the net contribution of the service sector proper was essentially zero. At the two-digit level, only the health services industry from services proper had a large negative impact on aggregate multifactor productivity (–0.1). Slifman and Corrado did not report results below the one-digit level outside of services proper. We would focus more attention on nonmanufacturing industries outside of services proper than did Slifman and Corrado.

The structure and logic of the Slifman-Corrado exercise are central to the case that low productivity betrays price measurement bias. As we understand it, the experiment involved the following steps:

1. Substitution of an assumed zero productivity trend for the measured trend wherever the measured trend was negative.
2. Adjustment of the industry output trend up by the same amount as productivity.
3. Aggregation of the adjusted output measures and recalculation of nonfarm business productivity.

The logic of step (1) is that the long-term trends are below a plausible lower bound for labor productivity, so we should prefer the lower bound to the actual measure. The logic of step (2) rests on the premise that any measurement problem must be with output. The logic is appropriate so long as there were no grounds to suspect that the hours' trends were significantly overestimated in these industries.

The data in table 5 permit us to do a similar exercise using multifactor productivity data. To figure out how much we would raise aggregate multifactor productivity by raising multifactor productivity to zero in each industry for which it is negative, all we would have to do is add up the negative contributions. The negative contributions shown in table 5 for the 1977–92 period total about –0.6 percent, using either the BLS output-based dataset or –0.8 percent, using the "Bureau of Economic Analysis" output-based dataset. When we include the small contributions of those industries which are not displayed in table 5 because of our rounding criterion, we estimate that negative productivity industries make a –0.61-percent Domar "contribution" to aggregate productivity, based on the BLS data. Thus, adjusting all negative multifactor productivity trends to zero would imply a 0.61-percent upward adjustment to aggregate productivity. This can be compared with the 0.5-percent adjustment that Slifman and Corrado calculated. The difference is mainly attributable to the fact that capital-labor ratios and intermediate input-labor ratios have risen in most industries. Because of this, multifactor productivity trends tend to be lower than labor productivity trends. Therefore, a zero multifactor productivity trend usually represents a tougher criterion for the "plausible lower bound" for productivity than does a zero output-per-hour trend.

However, one other consideration influences the application of the Slifman and Corrado logic to multifactor productivity data in a Domar framework. Some industries deliver part of their output to other industries. These items become intermediate inputs to the receiving industry. In constructing our measures, we have used the same price indexes to deflate these deliveries on the input side as we do on the output side.

So if one suspects, as Slifman and Corrado did, that the output trend is biased because of price deflation, then the logic of the exercise dictates that we adjust the input trends for industries buying the output of industries with negative multifactor productivity. We need to adjust the trends for these inputs by the same amounts as the trends for their outputs. (See the box on page 51.)

After accounting for these input effects, we estimate that adjusting negative multifactor productivity trends to zero during 1977–92 would raise private business multifactor productivity by about 0.4 percent. This is the case with either of the datasets that we tested. This agrees, roughly and perhaps coincidentally, with the result of the Slifman-Corrado exercise. Table 6 presents details of these calculations for 1977–92. It shows the effects on multifactor productivity in private business and manufacturing when adjusting both the outputs of each nonmanufacturing industry with negative multifactor productivity and the inputs of all industries using their outputs. We have shown these effects to two decimal places and we have shown the effects for all nonmanufacturing industries with negative measured multifactor productivity trends. Because it is arbitrary to assume that multifactor productivity grew 0 percent in these industries, we have also displayed results (second panel) which assume a second arbitrary (1 percent) multifactor productivity trend for the same set of industries (those with negative measured multifactor productivity). We have repeated all of the calculations using the BLS output based dataset (first two columns) and the Bureau of Economic Analysis output based dataset (final two columns). We think table 6 represents a better basis than table 5 for tracing the *potential* implications of *alleged* output measurement biases for aggregate productivity.

With the substitution of 1 percent multifactor productivity trends for industries with negative trends, private business multifactor productivity (lower part of the table) would be raised by about 0.8 percent (BLS) or 0.9 percent (Bureau of Economic Analysis). Depending on whether we assume zero or 1 percent multifactor productivity for these industries, the published private business multifactor productivity growth trend since the late 1970s of about 0.2 percent per year might be raised to 0.6 percent or 1.0 percent. If either assumption were correct, it would account partially, but not fully, for the post-1973 slowdown in productivity and for the divergence of manufacturing and business productivity trends.

We would like to direct attention to the industry detail presented in the third column of the top part of the table (using "Bureau of Economic Analysis-based" output trends, and adjusting where necessary to raise negative industry multifactor productivity trends to zero). Perhaps, for researchers, this is the most useful set of results for thinking about measurement issues, because it starts with the Bureau of Economic Analysis' own estimates of the trends in gross output. This column

Table 6. Effects on aggregate multifactor productivity trends by two adjustments for tracing possible output measurement biases1977–92

[Compounded annual rates]

SIC	Adjusted Industry	Bureau of Labor Statistics output based on—		Bureau of Economic Analysis output based on—	
		Private business multifactor productivity	Manufacturing multifactor productivity	Private business multifactor productivity	Manufacturing multifactor productivity
	Adjustment 1—Sufficient to produce zero percent industry multifactor productivity growth:				
	Total effects	0.41	–0.14	0.44	–0.17
13	Oil and gas extraction	–.02	–.08	.00	–.10
15–17	Construction	.06	–.00	.12	–.00
41	Local passenger transit	.00	–.00	.00	–.00
45	Transportation by air	.02	–.01	.02	–.01
49	Electric, gas, and sanitary services	.03	–.02	.06	–.04
60, 61, 67	Credit agencies, etc.	.08	–.01	.09	–.01
63	Insurance carriers	.14	–.01	.10	–.00
64	Insurance agents, brokers	.00	–.00	.00	–.00
65– 66	Real estate	.01	–.00	.02	–.00
70	Hotels and other lodging	.02	–.01	.00	–.00
75	Auto repair, etc.	.03	–.01	.00	–.00
80	Health services	.03	–.00	.05	–.00
	Adjustment 2—Sufficient to produce 1 percent industry multifactor productivity growth:				
	Total effects	.83	–.25	.87	–.28
13	Oil and gas extraction	–.03	–.12	–.03	–.14
15–17	Construction	.19	–.00	.25	–.01
41	Local passenger transit	.01	–.00	.01	–.00
45	Transportation by air	.03	–.01	.03	–.00
49	Electric, gas, and sanitary services	.07	–.05	.10	–.07
60, 61, 67	Credit agencies, etc.	.12	–.02	.13	–.02
63	Insurance carriers	.19	–.01	.15	–.01
64	Insurance agents, brokers	.00	–.00	.00	–.00
65– 66	Real estate	.07	–.01	.08	–.01
70	Hotels and other lodging	.03	–.01	.01	–.00
75	Auto repair, etc.	.06	–.02	.03	–.01
80	Health services	.10	–.00	.11	–.00

is similar in coverage to the last column of table 5. However, in table 6, the effects of adjusting intermediate inputs have been accounted for as well as the effects of adjusting outputs. In general, the industry contributions are smaller in table 6 than in table 5 and the ranking of the industry contributions changes slightly. A zero multifactor productivity trend in construction would result in a 0.12-percent increase in the private business multifactor productivity trend. Adjustment of insurance carriers would have an impact of 0.10 percent, while the impact of adjusting banking would be 0.09 percent. These three are worthy of emphasis, as they account for 0.31 percent of the 0.44 percent increase to the aggregate from "zeroing out" all of the negative multifactor productivity trends at the industry level. There would also be notable effects from raising the multifactor productivity trends of utilities (0.06 percent) and health services (0.05 percent). A factor limiting the importance of health services in our analysis is that many of these services are provided by government or nonprofit institutions, both of which are excluded from the private business sector. For no other industry does the multifactor productivity adjustment raise the private business multifactor productivity trend by more than 0.02 percent.

Possible interpretations of the results. There are various possible explanations for the negative multifactor productivity trends by industry. As we mentioned earlier, one explanation is that the measures are correct. If one suspects that they are not, then it would be useful to think through the measurement process to identify where we could be going wrong. Multifactor productivity is measured by dividing measures of output, Y, by input, I:

$$MFP = Y / I .$$

Therefore, the trend in multifactor productivity would be too low or negative if the output trend were too low or if the input trend were too high.

There are many possible avenues by which inputs could be biased. The data on intermediate inputs come from input-output tables. Some researchers are skeptical of these data. Capital measurement involves some strong assumptions. Even the allocation of labor hours to industries might be suspected. In addition, in the multifactor productivity measurement, we created a "combined input" measure by aggregating the various types of inputs with value weights. This is rationalized on assumptions of competitive input factor markets and constant returns to scale production. These assumptions represent additional potential sources of measurement bias.

An alternative explanation is that some industry output trends are too low. (Of course, there could be some combination of explanations also.) To determine the possible sources of output bias, the methods used to measure output must be examined. The output measures in our dataset are created in several different ways. Output is sometimes measured using a deflated value approach. The nominal value of the output (V_y) is divided by a corresponding output price index (P_y):

$$Y = V_y / P_y .$$

There certainly could be biases in some of our estimated trends in nominal industry output. An alternative, which many authors have focused on, is that there could be upward biases in the price index number trends used in deflation. But there are other possibilities. Price indexes are not available for every output and so the builders of a comprehensive dataset like the national income and product accounts must find other ways to make estimates. For some commodities, the prices used in the deflated value approach are prices for a different commodity to which they have been matched. In other cases, they are input price indexes or input cost indexes. Finally, some "prices" are derived implicitly by dividing the nominal value of output by a direct measure of output or by an estimate of output made by assuming that output grew at the same rate as an input.

If the input and nominal output measures are not seriously biased, then the hypothetical problem comes down to *the allocation of the nominal output trend into a price trend and a quantity trend*. Assuming all of this, it would be good to know what combination of price index numbers is used to measure output in industries with negative multifactor productivity trends. Lucy Eldridge has estimated that for 1997 data, about 58 percent of business output was constructed at the Bureau of Economic Analysis by CPI deflation and another 15 percent by PPI deflation.[42] However, in two of the three industries (banking and construction) for which negative multifactor productivity trends are most important to the aggregate, it appears that extensive use is made of methods of output measurement that do not involve deflation with price index numbers.[43] Since 1994, PPI deflation has been used by the Bureau of Economic Analysis to deflate the majority of health services output. However, the health services CPI was used for the period covered by this article. Finally, it appears that CPI deflation is used for all of insurance, except life insurance, for which, a "composite index of input prices" is used. However, for health and casualty insurance, for which CPI deflation is used, the nominal output concept is one of premiums less benefits, and premiums and benefits are deflated separately.

While a comprehensive review of these methods is beyond the scope of this article, we would like to highlight two issues. The first of these relates to banking. About 82 percent of final demand expenditures on banking output are "financial services furnished without payment." Real final demand for these services is measured by extrapolation with "paid employee hours." This is, in effect, *an assumption of a zero trend in labor productivity*. The negative multifactor productivity trend reflects our use of this same labor productivity assumption in measuring gross output[44] coupled with large increases in capital and intermediate inputs used by banks. We should note that the CPI is used to deflate the 18 percent of nominal output representing bank service charges.

The second issue is that input cost indexes and other input price indexes appear to have been used extensively[45] as output deflators for parts of construction, and for life insurance output.[46] Use of these methods can lead to restrictive productivity measures. For example, if wages, *w*, are used to deflate nominal output, then we have virtually assumed that labor productivity does not change. Labor productivity, *LP*, would change only if the share (S_L) of labor compensation (w_L) in nominal output (V_Y) changes:

$$LP = Y / L = (V_Y / w) / L = 1/s_L .$$

Since 1947, business sector labor productivity has grown steadily, while the share of labor experienced only small variations. There are analogous implications for productivity when prices of other inputs are used in deflating output.

This article does not attempt to study methodological issues in the CPI. However, our results can shed some light on the extent to which slow productivity growth may be a reflection of CPI bias. As we have seen, the CPI plays only a minor role in the Bureau of Economic Analysis output measurement for banking and construction. CPI components do play a larger roles for insurance, where they are used for all types of insurance except life insurance. However, for health and casualty insurance outputs, output is defined as premiums less claims. Output is then deflated using price indexes for premiums or claims, or both. If these output measures are biased, it is unclear just what roles nominal output and deflation play.

In general, it does not seem reasonable to infer CPI bias from the declines in multifactor productivity in any of the three industries which we have emphasized. We stress that our evidence does not rule out the possibility that alleged bias in components of the CPI affects productivity measures. It is possible that bias in certain CPI components could contribute to the negative multifactor productivity trends for the five industries that we have identified. It is also possible that CPI components could contribute to bias in other final demand components associated with increases in multifactor productivity. For example, even though multifactor productivity trends for manufacturing and communications are positive, they could be understated due to CPI bias. Yet, it is still hard to see how our industry multifactor productivity trends could back up the assertion that low aggregate productivity trends are a symptom of CPI bias.

Conclusions

We found three industries (construction, insurance, and banking), that had negative multifactor productivity trends during the 1977–92 period and, in our framework, those trends were significant enough to lower the business sector productivity trend by about 0.1 percent per year each during the same period. We also found that negative multifactor productivity trends for utilities and for health services, and each trend was significant enough to lower the aggregate trend by about half as much.

In theory, declining multifactor productivity could occur if there were causes, such as forgotten technology, decreasing returns to scale in a growing sector, underutilization of capital in a shrinking sector, or some other decrease in efficiency, perhaps due to institutional changes. If bona fide, the multifactor productivity declines over such a long period represent vast losses in efficiency.

There are certainly some important examples of anecdotal evidence working against multifactor productivity growth in these five industries. However, there are also many anecdotal examples of productivity improvements, and so, it is difficult to believe that there has been such a large net decline in multifactor productivity in this block of industries.

We outlined, in some detail, a few possible sources of bias in the measurement of inputs and outputs. There are important empirical and theoretical questions on the input side, concerning how the data we use were put together by others and also concerning how we have used them. The answers to these questions could imply input bias. We have considered the issue of manufacturers purchasing labor services from service industries. In concept, we have accounted for this issue in our multifactor productivity trends, although we must acknowledge that the data we have used might be weak. Other than this issue, we are not aware of any grounds to suspect that input trends are substantially and systematically overstated in any of the five industries with significant negative multifactor productivity trends or in the private business sector as a whole.

We suspect that some output trends are indeed downward biased. It is, of course, possible that the trends in nominal output are downward biased. Here, we have another possibility that cannot be ruled out. But again, the measurement of nominal transactions is relatively straightforward,[47] and we have no particular reason to suspect a serious bias in any particular direction.

The remaining explanation would be a bias in the decomposition of output trends into quantity trends and price trends. While we have no empirical basis for assigning weight to the various explanations, there is good reason to suspect that bias in the output quantity/price allocation is a dominant explanation for two of the industries we have identified. In banking, employment values have been used in measuring output, while in construction, input prices have been used in measuring output prices. In either case, strong and conservative assumptions about productivity growth are implicit. It is less clear what is causing the negative multifactor productivity trends for insurance, health services, and utilities.

Finally, the services that the insurance, banking, and health services industries provide are among the most difficult to conceptualize within the context of economic measurement. The absence of a good scientific basis for measuring these outputs probably accounts for the fact that price indexes are sparse as well as the apparent reluctance of statistical agencies to impute specific productivity trends. Fortunately, there are data improvement initiatives pending at BLS, at the Bureau of Economic Analysis,[48] and at the Bureau of the Census, addressing measurement of real output in the industries we have emphasized and in other industries.[49] In some cases, new methods already have been implemented. Use of these new methods does not necessarily affect the data prior to 1992, used in this study.

However, there are industries with complex measurement issues for which neither government nor academic researchers have been able to develop widely accepted approaches. Pending solid and usable research in these areas, we need to continue publishing aggregate datasets such as the national accounts. It is necessary for the national accounts to continue to make estimates in situations for which price indexes are either inadequate or unavailable. In doing so, we would suggest exploring alternatives to the assumption of constant labor productivity as the basis for extrapolating real output trends. One possibility is to assume that the multifactor productivity trend is zero. While still conservative, this approach would consider growth in several inputs, rather than just one. Another possibility is to use independent data on industry labor productivity trends, in addition to employment, in estimating real output trends.

Footnotes

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[1] These industries are defined in the *Standard Industrial Classification Manual: 1987* (U.S. Office of Management and Budget).

[2] See William Gullickson and Michael J. Harper, "Production Functions, Input-Output Tables, and the Relationship Between Industry and Aggregate Productivity Measures" (Bureau of Labor Statistics, Office of Productivity and Technology, 1999).

[3] L. Slifman and C. Corrado, "Decomposition of Productivity and Unit Costs," *Occassional Staff Studies*, OSS-1 (Washington, DC, Federal Reserve Board, 1996). See also "Final Report of the Advisory Commission to Study the Consumer Price Index," Senate Print (U.S. Senate, Committee on Finance, December 1996), pp. 104–72.

[4] D. W. Jorgenson and Z. Griliches, "The Explanation of Productivity Change," *Review of Economic Studies*, July 1967, pp. 249–82.

[5] D. W. Jorgenson, F. M. Gollop, and B. M. Fraumeni, *Productivity and U.S. Economic Growth* (Cambridge, MA, Harvard University Press, 1987); and Z. Griliches, "Productivity, R&D, and the Data Constraint," Presidential Address, *American Economic Review*, March 1994, pp. 1–23.

[6] Eventually, we would expect the industry to return to an optimal amount of capital and resume productivity growth. However, in industries affected by technological change or the introduction of imports, this might take decades. A few examples where this has happened in the United States are the railroad, steel, and textile industries. Quality may also decline, and anecdotes about declining service quality are abundant.

[7] J. Madrick, "Computers: Waiting for the Revolution," *The New York Review of Books*, Mar. 26, 1998, pp. 29–33.

[8] See J. R. Norsworthy, M. J. Harper, and K. Kunze, "The Slowdown in Productivity Growth: Analysis of Some Contributing Factors," *Brookings Papers on Economic Activity*, December 1979, pp. 387–421. While it was noted that productivity had slowed down more in nonfarm business than in manufacturing, the slowdown appeared to be large in both sectors, using data then available. The study focused mainly on how inputs accounted for the slowdown rather than on the divergence.

[9] R. M. Solow, "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, vol. 39, no. 3, 1957, pp. 312–20.

[10] As Solow pointed out, the goal of a measure of technological change is never fully realized. Multifactor productivity, the ratio of output to inputs, reflects many influences in addition to efficiency and technological change. Among them are the effects of returns to scale, unmeasured inputs, and measurement errors for inputs or outputs. However, multifactor productivity measures are a step closer to the goal than are measures of output per hour in that multifactor productivity "adjusts out" the effects of increased capital intensity. Solow's work is built on neoclassical concepts originating in earlier work by P. A. Samuelson, *Foundations of Economic Analysis* (Cambridge, MA, Harvard University Press, 1947). Unknown to Solow at the time, equations similar to Solow's had been derived by Jan Tinbergen, "Zur theorie der langristigen wirtschaftsentwicklung," *Weltwirtschaftliches Archiv.*, Band, vol. 55, no. 11, 1942, pp. 511–49. English translation, "On the Theory of Trend Movements," in L. H. Klassen, L. M. Koyck, and H. J. Witteveen, eds., *Jan Tinbergen, Selected Papers* (Amsterdam, North Holland, 1959).

[11] See *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, September 1983). At the time BLS began publishing measures, data were only available through 1981. Evidence of a productivity recovery in manufacturing had not yet emerged.

[12] Research on the composition of the labor force by Larry Rosenblum, Mary Jablonski, and Kent Kunze led to the publication of *Labor Composition and U.S. Productivity Growth, 1948–90*, Bulletin 2426 (Bureau of Labor Statistics, December 1993).

[13] The use of superlative index numbers in BLS productivity work is described in E. R. Dean, , M. J. Harper, and M. K. Sherwood, "Productivity Measurement with Changing Weight Indices of Output and Inputs," *Industry Productivity: International Comparison and Measurement Issues* (Paris, The Organisation for Economic Co-Operation and Development, 1996), pp. 183–215.

[14] W. E. Diewert, "Exact and Superlative Index Numbers," *Journal of Econometrics*, vol. 4, no. 4, 1976, pp. 115–45.

[15] Formally, these formulas assume fewer restrictions about substitution than do traditional fixed-weighted aggregation procedures. Frequently, superlative index formulas are calculated for successive pairs of years, the resulting growth rates being "chained" into an index. This technique effectively keeps the weights current.

[16] In its productivity work, BLS defines nominal gross output as the value of shipments less inventory change. The Bureau of Economic Analysis also prepares "gross output" to measure gross product originating (GPO). It makes additional adjustments to "gross output" to ensure conformity of the GPO data with the national accounts. We use these gross output measures, avail-

able 1977–93, in a dataset we construct later in this article.

[17] L. R. Mishel, *Manufacturing Numbers: How Inaccurate Statistics Conceal U.S. Industrial Decline* (Washington, DC, Economic Policy Institute, April 1988), and "The Late Great Debate on Deindustrialization," *Challenge*, January-February, 1989, pp. 35–43.

[18] An interim report on the redesign effort was presented at a Conference on Research in Income and Wealth meeting in 1990. See M. F. Mohr, "Recent and Planned Improvements in the Measurement and Deflation of Services Outputs and Inputs in BEA's Gross Product Originating Estimates," in Zvi Griliches, ed., *Output Measurement in the Service Sectors* (Chicago, The University of Chicago Press, 1992), pp. 25–71.

[19] For a description of these new measures, see R. Parker, "Gross Product by Industry, 1977–90," *Survey of Current Business*, May 1993, pp. 33–54. The improvements included using new sources of data to allocate factor incomes to industries, more extensive use of the Bureau of Economic Analysis preferred double deflation method, and incorporation of additional data on import prices.

[20] E. D. Domar, "On the Measurement of Technological Change," *Economic Journal*, December 1961, pp. 709–29.

[21] The term "sectoral output" was coined by Frank Gollop. See F. M. Gollop, "Accounting for Intermediate Input: The Link Between Sectoral and Aggregate Measures of Productivity," *Measurement and Interpretation of Productivity* (Washington, DC, National Academy of Sciences, 1979), pp. 318–33. This study was part of a National Academy of Sciences report recommending that BLS prepare measures of multifactor productivity. The section written by Gollop recommended that BLS follow these definitional conventions. The Domar framework was also used by C. R. Hulten to explore the direct and secondary implications of technological advances in a given industry. See C. R. Hulten, "Growth Accounting with Intermediate Inputs," *Review of Economic Studies*, October 1978, pp. 511–18.

[22] Domar, "Measurement of Technological Change."

[23] Note that all capital goods created by an industry are treated as outputs. In the neoclassical literature, capital goods are not treated as direct inputs, whether obtained from the same industry or a different industry. Capital inputs are instead defined as "service flows" associated with capital goods. For a discussion on the measurement of capital services, see M. J. Harper, "Estimating Capital Inputs for Productivity Measurement: An Overview of Concepts and Methods" (Bureau of Labor Statistics, Office of Productivity and Technology, 1997).

[24] W. Gullickson, and M. J. Harper, "Production Functions, Input-Output Tables."

[25] Prior to 1996, BLS used a net output framework. Manufacturing multifactor productivity measures compared GPO to inputs of capital and labor. (The Bureau of Economic Analysis GPO accounts do not explicitly match capital and labor inputs to GPO.) Since 1996, BLS has published, instead, a manufacturing multifactor productivity measure using the sectoral concept. BLS continues to publish multifactor productivity measures for the more aggregate private business and private nonfarm business sectors which compare national accounts outputs to capital and labor inputs. We have simplified with respect to the index number issue in this schematic. In either the sectoral or net framework, only nominal outputs are additive. Real outputs and inputs must be combined with index number formulas. In Gullickson and Harper, "Production Functions, Input-Output Tables," we discuss real outputs and inputs in terms of "value share weighted growth rates." We also explicitly consider the issue of imported inputs.

[26] In this example, we are referring to instantaneous rates of change to avoid index number issues.

[27] BLS does publish productivity measures for selected nonmanufacturing industries.

[28] In particular, the output is "sectoral output," that is, gross output net of intraindustry materials flowing between manufacturing establishments. Also, inputs are formulated to include materials and services purchased by manufactures from outside manufacturing. Input-output tables were used in estimating these intra- and inter-industry transactions. See "Multifactor Productivity Trends, 1994," USDL 95–518 (U.S. Department of Labor) Jan. 17, 1996. In this press release, we substituted these measures of manufacturing multifactor productivity for the measures comparing real GPO with inputs of capital and labor (which we had used in earlier multifactor productivity news releases). Also, see W. Gullickson, Measurement of productivity growth in U.S. manufacturing," *Monthly Labor Review*, July 1995, pp. 13–28.

[29] The Bureau of Economic Analysis output measure used by BLS for U.S. private business sector multifactor productivity falls slightly short of being "sectoral output." This sector does use some intermediate inputs obtained from "outside," mainly imports. For strict comparability in the Domar sense, the multifactor productivity measures should include imports along with capital and labor inputs. We have looked into this, and it appears inclusion of imports would have very little effect on the multifactor productivity trends. A formula for the bias is derived in Gullickson and Harper, "Production Functions, Input-Output Tables." We do not think this issue significantly affects the conclusions that can be drawn from this table. Note that BLS does include imported intermediate inputs in its manufacturing inputs. At some point, BLS may consider including them as inputs to private business.

[30] The output per hour measures for business and nonfarm business in table 1 include government enterprises. These enterprises are excluded from the "private" business and "private" nonfarm business sectors for which multifactor productivity is measured, as in table 2.

[31] W. Gullickson, and M. J. Harper, "Multifactor Productivity in U.S. Manufacturing, 1949–83," *Monthly Labor Review*, October 1987, pp. 18–28.

[32] We arrive at the 0.7 figure by comparing *the trend of an aggregate* of (a) directly employed labor hours and (b) purchased services inputs with *the trend in directly employed labor hours* alone. To aggregate hours and services, we use the Törnqvist index formula and cost share weights as we do in aggregating all inputs for multifactor productivity measurement.

[33] Gullickson and Harper, "Production Functions, Input-Output Tables."

[34] A. M. Lawson, "Benchmark Input-Output Accounts for the U. S. Economy, 1992," *Survey of Current Business*, November 1997, pp. 36–82.

[35] There are no estimates for a few industries, notably banking. See footnote 5 in the appendix.

[36] S. K. S. Lum and R. E. Yuskavage, "Gross Product by Industry, 1947–96," *Survey of Current Business*, November, pp. 20–34.

[37] For readers interested in seeing more significant digits, in table 6, we present a similar exercise that shows contributions to two decimal places.

[38] We have included in this total an adjustment term for government enterprises. BLS presently excludes the GPO of government enterprises from its published private business sector measures. This exclusion represents a departure from the sectoral output concept because we have not properly accounted, in the sectoral output sense, for the fact that government enterprises trade with other private businesses. We have computed the adjustment term by applying a weight to the trend in the ratio of (a) government enterprise real GPO to (b) real intermediate inputs purchased by government enterprise from other businesses. This weight is the negative of the nominal GPO of government enterprises divided by the nominal output of private business. The adjustment term, which is reported for 1977–93 in table 6 is small and negative. The adjustment is effectively a subtraction, in the spirit of Domar weighting, of a dummy productivity trend.

[39] The published measures reflect "labor composition effects" based on the education and experience of workers. We are not able to disaggregate labor composition effects to the industry level, so instead, we use hours. However, when we aggregate multifactor productivity, using Domar weights, we effectively weight labor hours in different industries with their compensation shares. This differs from a total-hours measure by what is sometimes called an industry reallocation effect. The adjustment we make to the last line in table 5 is the difference between this reallocation effect and the labor composition effect used by BLS in its published multifactor productivity measures. The published aggregates are inconsistent with the industry data on one other score: the published measures exclude imported intermediate inputs from both outputs and inputs. These exclusions are inconsistent with Domar's model. However, these exclusions are not only small, but they affect output and input trends at the same rate. They approximately cancel out and so we can safely neglect them.

[40] The published BLS private business multifactor productivity measure is

based on the product side of the national accounts, one component of which is "net exports" (exports minus imports). In the National Accounts, imported goods, whether they are consumed by final users or by industries as intermediate inputs, are deducted from exports in computing GDP and private business output. Frank Gollop has noted that imported intermediates should be considered inputs in aggregate productivity measures rather than being subtracted from output. See F. M. Gollop, "Growth Accounting in an Open Economy," *Boston College Working Papers in Economics* (March 1981).

In our industry measures, imported intermediate inputs are included as inputs. Imported intermediates consist of the three items identifiable in the national accounts import statistics as intermediates (durable industrial supplies and materials; nondurable industrial supplies and materials; and petroleum and products) plus auto parts and computer peripherals and parts. The share of these inputs (among all inputs) is about 6 percent in 1980. From the standpoint of the sectoral output concept, imported intermediate inputs are an input to the business sector. Because they are deducted from GDP in arriving at the BLS measure of business output rather than being included in inputs, there could be a bias in the resultant sectoral multifactor productivity measure. However, the bias is likely to be quite small. The fact that we have treated imported intermediates correctly in the industry measures could account for some of the small discrepancy between the aggregates obtained from Domar aggregation of the industry measures and the published measures.

41 Slifman and Corrado, "Decomposition of Productivity."

42 Lucy Eldridge, "How price indexes affect BLS productivity measures," *Monthly Labor Review*, this issue, pp. 35–46.

43 These methods are described in Bureau of Economic Analysis "Updated Summary NIPA Methodologies," *Survey of Current Business*, September 1988, pp. 14–35.

44 One could contend that we have set up a "straw dog" by applying the employment extrapolation assumption to gross output. The national accounts apply this assumption in estimation of real final demand and in estimation of real GPO (which are in concept quite different from one another and from gross output). See S. K. S. Lum and R. E.Yuskavage, "Gross Product by Industry, 1947–96," *Survey of Current Business*, November 1997, pp. 20–34. Lum and Yuskavage do not make an estimate of real gross output for banking. The bottom line here is that employment assumptions are not appropriate if we are to use any of these output measures to measure productivity.

45 We have not determined precisely what fraction of each of these industries' outputs reflects these methods.

46 Bureau of Economic Analysis "Updated Summary," 1988, pp. 14–35.

47 Measurement of nominal transactions is not so straightforward in banking. However, this is of little relevance to the possibility that nominal output mismeasurement is responsible for negative multifactor productivity because the national accounts output estimates for banking are based mainly on employment extrapolation.

48 "BEA's Mid Decade Strategic Plan: A Progress Report" *Survey of Current Business* (Bureau of Economic Analysis, June 1996), pp. 52–55.

49 Dean, Harper, and Sherwood, "Productivity Measurement with Changing Weight."

Appendix: Construction of the data for industries

In this appendix, we discuss how the data were assembled for tables 4, 5, and 6. If we had a consistent set of periodic input-output tables, along with a complete detailed set of commodity price indexes, we could construct accurate and consistent industry and aggregate multifactor productivity measures. In practice, available data fall short of this ideal. Assumptions must be made to fill in some of the cells of the input-output tables. Available input-output tables reflect industry "reclassifications" which reassign the industry of some inputs and outputs associated with secondary products to other Standard Industrial Classification (SIC) categories. In actual practice we lack a "time series" of tables: the only input-output table consistent with the current U.S. national accounts is the 1987 table. Finally, price indexes do not exist for many commodities and have to be estimated in the national accounts.

The 1977 and 1982 tables used in this article are part of the current BLS economic growth model, and have been closely conformed to current national accounts practices by the BLS Office of Employment Projections. Pre-1977 tables have been conformed as closely as possible to the 1987 SIC by the authors. The Bureau of Economic Analysis does not retroactively conform older tables and time series to current definitions, so any conceptual or methodological changes introduced to the national accounts since these older data were prepared might not be reflected accurately in these older data.

Output

The gross output measures are based on data available from three sources: 1) the BLS Office of Employment Projections (used for 1958–77 and for 1977–92 in one variant we report), 2) the Bureau of Economic Analysis gross product-by-industry program (used for 1977–92 in a second variant we report), and 3) a 1975 study by Jack Faucett Associates commissioned by the employment projections office (used for 1947–58).[1] While pre-1977 data are not fully consistent with the present national accounts, we include them to extend this exercise to cover a longer time span with the best available data.

The study by the employment projections staff compiles gross output and output price series for each of 183 industries for purposes of an economic growth model.[2] Values of production and output measures in the collection are constructed by interpolation between input-output tables, using interpolator series from the best available sources;[3] the input-output benchmarks used by the staff are those presently part of their growth model, that is, 1977, 1982, and 1987. Earlier tables for 1963, 1967, and 1972 were conformed to the 1987 SIC as closely as possible by the authors of this article, and the values of production for years 1958–76, from the Office of Employment Projections, are adjusted to these benchmarks as well. The authors also adjusted the employment projections series on output to conform with the 1992 input-output table published recently by the Bureau of Economic Analysis and described by A. M. Lawson .[4]

The work of the Bureau of Economic Analysis (which, as stated previously, we use for multifactor productivity calculations for 1977–92 and which we report as a "variant" to multifactor productivity based on employment projections output estimates) compiles the value of gross production and corresponding price series for most two-digit industries.[5] One use that the Bureau of Economic Analysis makes of these data is in the estimation of gross product originating (GPO) by industry. These data extend back to 1977, with problems in a few industries due to the revision of the SIC system in 1987. For these industries, we base output on data from the Employment Projections work described in the previous paragraph. These industries are water transportation, transportation services, credit agencies, real estate, business services, legal services, and government enterprises.

The present Bureau of Economic Analysis' values of production and price series for two-digit industries, which are available for the years 1977 forward, are aggregated to the 35-industry level and compared to their counterparts from the Office of Employment Projections for consistency. The employment projections' production and prices series for 1958–77 and the present Bureau of Economic Analysis series were linked in the year 1977, except cases in which there were SIC problems in the Bureau's data. The Bureau of Economic Analysis does not adjust data for prior years to conform to a revised SIC, but rather shows data for the years before the revision on the old basis, for the years after on the new basis, and the year of the change both ways. In this case, data for several industries on the basis of the 1987 SIC are available only after 1986.

Lastly, industry outputs are adjusted if necessary by the authors to reflect the concepts underlying the published BLS private business sector output measure. Because our purpose is to relate these industry productivity estimates with aggregates to assess the effect of measurement problems, the conventions we follow for the private business aggregate multifactor productivity measures are duplicated for industries. The industry measures are based partially on input-output tables, which are in turn based on the inclusive concept of GDP; several activities estimated in the national accounts are excluded from the private business sector, so some adjustments must be made.[6]

Capital

Capital input is measured following the same general procedures used by BLS for its major sector and manufacturing capital measures. Detailed specifications have been published by BLS previously.[7] This section provides a summary of data sources and procedures.

Capital measures cover inputs of equipment, structures, inventories, and land in each industry. For fixed depreciable assets (equipment and structures), constant and current dollar investment data are obtained for each of 25 detailed asset type categories from the Bureau of Economic Analysis study of two-digit capital, as described by A. J. Katz and S. W. Herman.[8] Constant-dollar yearend capital stocks are developed by applying the perpetual inventory method to constant-dollar investment. This method sums up weighted past investments to obtain an estimate of capital stock in the current period. The weights are determined by a fixed "efficiency schedule" which describes the marginal product of an asset, as it ages, relative to that of a new asset. This schedule is indexed to 1.0 for a new asset, and is assumed to decline slowly, early in an asset's life and more quickly later on. The schedule is gauged to the Bureau of Economic Analysis estimates of service lives.

Constant and current-dollar yearend stocks of inventories for each of three stages of processing are obtained for each two-digit industry from the Bureau of Economic Analysis from 1959 forward; estimates are made for 1949–58 starting with data from the Annual Survey of Manufactures. Land stocks for two-digit industries are based on Manvel's estimate of the ratio of land to structures in 1966[9] together, with the BLS estimate of the value of structures (the wealth stock) in 1967.

Real capital inputs of each asset type were then assumed proportional to stocks,[10] and a chained (Törnqvist) aggregate index of total capital input—equipment, structures, inventories, and land—were then obtained for each two-digit industry. The weights for this procedure are based on estimates of the shares of each type of capital in the current value of capital income. Total capital income, obtained from the national accounts, in each industry and year is allocated to asset-type categories by estimating an implicit rental price for each type.[11] The rental price model employed here adopts an *ex post* nominal rate of return with a 3-year moving average of asset-specific capital gains.

Labor

The labor measures used in this article are similar to those used in previous multifactor studies for major industrial sectors done by BLS. These measures have the large BLS employment survey sources in common with the major sector multifactor productivity work, the manufacturing KLEMS multifactor measures for two-digit industries, and the BLS quarterly labor productivity program. A complete description of the labor measures underlying the output per hour and major sector multifactor productivity measures can be found in prior BLS publications.[12]

Labor input is measured in terms of undifferentiated (that is, unadjusted for skill or wage levels) hours at work. The primary source underlying these estimates is the BLS Current Employment Statistics Survey program which provides employee hours paid, supplemented by Current Population Survey (CPS) data on proprietors and special BLS surveys of differences between hours paid and hours worked. The Current Employment Statistics Survey provides monthly survey data on total employment and, for manufacturing, average weekly hours of production workers, and, for nonmanufacturing, average weekly hours of nonsupervisory workers. Average weekly hours of nonproduction workers in manufacturing are estimated on the basis of data underlying the BLS quarterly labor measures for durable and nondurable manufacturing. Average weekly hours of supervisory workers outside of manufacturing are not collected and so these are also estimated.

The average weekly hours data collected in the Current Employment Statistics Survey reflect payroll hours. Thus, hours based on this source include paid leave time for holidays, vacations, sick and personal leave, as well as time spent at the work site. Given that productivity relates to production, it is desirable to have a labor-input measure based on hours actually worked, exclusive of such paid time off.

Production and nonsupervisory workers' hours paid, based on the Current Employment Statistics Survey, is adjusted to reflect hours at work through the use of hours worked/paid ratios available for each two-digit industry in manufacturing and for each one-digit industry outside of manufacturing.[13] For recent years, these ratios are based on the results of the BLS Hours-at-Work Survey, which gathers data on the hours at work and hours paid of nonsupervisory and production workers.[14] For years before 1981, the ratios are based on the BLS Survey of Employer Expenditures for Employee Compensation. This survey, which was conducted biennially from 1966 to 1974 and then for a final time in 1977, gathered information on hours paid and hours of paid leave for office and nonoffice workers.[15] Also, for the years 1959 and 1962, the BLS Survey of Employer Expenditure for Selected Supplementary Compensation Practices for Production and Related Workers in Manufacturing Industries provided the basis for hours worked/paid ratios for two-digit manufacturing industries.[16]

Due to the fact that the Current Employment Statistics Survey data include only wage and salary workers, data from the Current Population Survey are used for proprietors and unpaid family workers.[17] This survey, upon which industry estimates can be based back to 1961, provides the numbers of persons in both groups and their average weekly hours.

Intermediate inputs

The values of the intermediate inputs used by each nonmanufacturing industry are estimated from input-output tables maintained by the BLS Office of Employment Projections. These in turn are based on benchmark input-output tables prepared by the Bureau of Economic Analysis on the basis of a variety of sources.[18] Significant assumptions are made by the Bureau in preparing the details of these tables. The economic censuses systematically collect data on the *cost* of materials *by type* for manufacturing industries—but not for a majority of nonmanufacturing industries. Fortunately, there are data providing a reasonable basis for the *total cost* of intermediate inputs from the Internal Revenue Service, the censuses of industries,[19] and other special data available for particular industries.

Growth in the value of intermediates is estimated using the 183-sector input-output tables (provided by the Office of Employment Projections) for all benchmark years since 1963, together with less detailed tables for 1947, 1958, and 1963. The tables for 1977 and later are part of the present growth model maintained by the staff; 1963–72 benchmarks are from previous versions of that model, conformed as closely as possible to the present (1987 SIC-based) sector plan, and the less detailed tables for 1947, 1958, and 1963 are aggregates of the original, 80-sector tables published by BLS and the Bureau of Economic Analysis. Price series for each of the 183 industries in the present growth model (from the Office of Employment Projections) also are available for 1958 forward; from 1947 to 1958, prices are specially constructed.

The nominal values of intermediate inputs are constructed, in the Bureau of Economic Analysis tables and the employment projections tables, so as to ensure identities between: a) the total value of nominal output of each industry, b) the total value of the commodities which that industry makes, and c) the cost of inputs it uses.

For the calculation of multifactor productivity consistent with our alternative (Bureau of Economic Analysis gross) output trends for 1977–92, we have not actually set up a full set of data on outputs and inputs for each benchmark year. Instead, we started with the employment projections output based multifactor productivity trend for 1977–92 and estimated adjustments to this trend for two effects. One effect is rather simple and comes from substituting the Bureau's output trend for employment projections' output trend for each industry. A second effect is an input effect. The input adjustment for a given industry is a weighted average of the output trend adjustments to all *other* industries. The weights are 1997 and 1992 averages of a particular industry's shares in total input costs: the costs of the commodity inputs the *given* industry buys from the respective *other* industries. If we only accounted for the output effect, the Bureau of Economic Analysis output based multifactor productivity trends would no longer be accounting for the private business multifactor productivity trend. We introduced these input adjustment factors because we realized that adjustments to output alone would imply an inconsistency with an "ideal" nominal accounting structure.[20] By using these factors, the Bureau of Economic Analysis output based multifactor productivity trends approximately account for the published aggregates for the 1977–92 period.

Inputs are deflated using the output prices associated with each type of input being purchased. These prices, which were obtained by the authors from the Employment Projections Office, are based largely on deflators used by the Bureau of Economic Analysis in the national accounts (which, in turn, are based mainly, but not exclusively, on price data obtained from the Bureau of Labor Statistics CPI and PPI programs). "Real" intermediate inputs, by detailed type, are then aggregated into three categories (energy inputs, nonenergy materials, and business service inputs) using the Törnqvist index number formula.[21]

Footnotes to the appendix

[1] For years prior to 1958, values of production and prices are from the Faucett study, This source contains data for the years 1947 to 1972, for 151 industries in the growth model (from the Office of Employment Projections) at that time. See "Output and Employment for Input-output Sectors; Time Series Data," Jack Faucett Associates study, commissioned by the BLS Office of Employment Projections, 1975.

[2] These series, extend to 1958, are conformed to the recently published input-output tables, and are based on the 1987 SIC. An earlier version of this work was published as "Time Series Data for Input-Output Industries," Bulletin 2018 (Bureau of Labor Statistics, March 1979).

[3] "Methodology for Time Series Data on Industry Output Price, and Employment" (Bureau of Labor Statistics, Office of Employment Projections, 1995).

[4] A. M. Lawson, "Benchmark Input-Output Accounts for the U. S. Economy, 1992," *Survey of Current Business*, November, 1977, pp. 36–82.

[5] For those industries for which real gross output is unavailable from the Bureau of Economic Analysis, we use the estimates from the BLS Office of Employment Projections. This affects our banking result. The real gross output estimate for banking is made by extrapolating the input-output value with the real final demand estimate from the Bureau of Economic Analysis. By using this, we could be imparting a bias to the extent that the proportion of banking output going to final demand changes. However, because the real final demand trend is measured by extrapolating with employment, it is hard to say whether one measure is more biased than another. The point we make in our conclusions is that these assumptions might be reconsidered.

[6] The private business sector excludes the government and household industries (all labor), the product of nonprofit institutions, gross owner-occupied housing product, and the gross product originating of government enterprises. The government sector, household industry, and owner-occupied housing all appear identically on the income and product sides of the national accounts. Each is represented in the input-output tables as an industry selling only to final demand. Materials purchased by these sectors are treated as final consumption rather than as inputs to these sectors. Thus, gross output is equal to value added for these activities and the aggregate treatment can be extended to the industry decomposition simply by omitting these industries from our database.

Nonprofit institutions and government enterprises are slightly different in that they use intermediate inputs in the input-output tables. Thus, gross output is greater than the value-added (gross product originating) which we are excluding from GDP to get business sector gross product. The treatment of industries in these cases in the present dataset is not to ignore the industries altogether, but to remove the value-added. The value of production and output that remain for government enterprises and nonprofit institutions thus represents only the value and quantity of intermediates consumed in production.

[7] See *Trends in Multifactor Productivity, 1948–81*, Bulletin 2178 (Bureau of Labor Statistics, September 1983), Appendix C. This describes procedures used for major sector measures. A similar procedure was followed for the two-digit industry measures used in this article.

[8] A. J. Katz, and S. W. Herman, "Improved Estimates of Fixed Reproducible Tangible Wealth, 1929–95," *Survey of Current Business*, May, 1997, pp. 69–92.

[9] Allen D. Manvel, "Trends in the Value of Real Estate and Land, 1956–66," *National Commission on Urban Problems: Three Land Research Studies* (Washington, DC, U.S. Government Printing Office, 1968). Manvel estimates the ratio of the land's value to the value of structures in 1966 as .24.

[10] Barbara M. Fraumeni and Dale W. Jorgenson, "The Role of Capital in U.S. Economic Growth, 1948–76," in George M. von Furstenburg, ed., *Capital, Efficiency, and Growth* (Cambridge, MA, Ballinger Publishing Co., 1980), assume capital inputs are proportional to the previous yearend capital stock.

See also, Erwin W. Diewert, "Aggregation Problems in the Measurement of Capital," in Dan Usher, ed., *The Measurement of Capital* (Chicago, University of Chicago Press, 1980), pp. 433–528. Diewert derives a capital model in which capital inputs are assumed proportional to the present yearend stock. He also discusses the distribution. The BLS treatment is a compromise between these two models.

[11] A general derivation of the rental price formula consistent with this efficiency schedule, among others, was presented by Robert E. Hall, "Technical Change from the Point of View of the Dual," *Review of Economic Studies*, January 1968, pp. 35–46. The use of rental prices to allocate capital income was proposed by Laurits R. Christensen and Dale W. Jorgenson, "The Measurement of U.S. Real Capital Input, 1929–1967," *Review of Income and Wealth*, December 1969, pp. 292–320. BLS reviewed this rental price allocation procedure using a preliminary version of the data for the present study. See Michael J. Harper, Ernst R. Berndt, and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices" in Dale W. Jorgenson and Ralph Landon, eds., *Technology and Capital Formation* (Cambridge MA, The MIT Press, 1973), pp. 331–72.

[12] For a discussion of the labor input measures for large sectors, see *Trends in Multifactor Productivity,* pp. 66–68, and the *BLS Handbook of Methods, Bulletin* 2285 (Bureau of Labor Statistics, 1988), pp. 70–71. For a complete description of the Current Employment Statistics Survey, see pp. 13–27 and for the Current Population Survey, see pp. 3–12.

[13] The hours at work series are fully described in 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.

[14] The Hours-at-Work Survey was first presented in Kent Kunze, "A New BLS survey measures the ratio of hours worked to hours paid," *Monthly Labor Review,* June 1984, pp. 3–7. Kunze updated those survey results in a subsequent research summary, "Hours at work increase relative to hours paid" *Monthly Labor Review,* June 1985, pp. 44–46.

The Hours-at-Work Survey, which is done in conjunction with the Current Employment Statistics Survey, covered about 4,500 respondents in the first 6 years of the survey (1981–86) and 5,500 since 1987. The survey is therefore relatively small, and there is the possibility that (especially at the two-digit level) the statistical error associated with the small sample size exceeds the benefit of the adjustment. In considering whether to incorporate the ratios at this level, the approach taken was to consider: a) the empirical importance of *systematic* changes in the hours worked measure (that is, trends and short-term changes apparently related to the business cycle); b) the amount of error being introduced by the small sample size for any industry; and, c) an assessment of sampling error already present in other KLEMS data, especially that reported for the Current Employment Statistics Survey employment and average weekly hours estimates.

Regressions designed to show trends in the ratios and their sensitivity to output levels generally indicated both trend and cyclical movements. On average, the trend movement in the ratio is 0.2 percent per year. Significant coefficients on output growth occur in three industries at the 95-percent confidence level and in eight industries at the 80-percent confidence level. Standard percentage error estimates for the hours worked/paid ratios, computed for each year and for each industry from the variation in the sample, were typically slightly less than 0.50 (half of 1 percent change in the ratio, in which equality of hours paid and worked is represented by 100.0) and ranged between 0.14 percent for tobacco and 0.69 percent for petroleum products.

Standard percentage errors in annual changes in the Hours-at-Work Survey were compared with standard percentage errors in monthly changes in Current Employment Statistics Survey employment and hours. In about half the cases, the Hours-at-Work Survey represents a larger "proportion of the error" than the Current Employment Statistics Survey, suggesting that the hours-at-work error is probably about the same as the error inherent in the Current Employment Statistics Survey.

[15] For details regarding the Survey of Employer Expenditures for Employee Compensation, see *Employee Compensation in the Private Nonfarm Economy, 1974,* Bulletin 1963 (Bureau of Labor Statistics, 1977).

[16] This survey is described in *Employer Expenditures for Selected Supplementary Compensation Practices for Production and Related Workers; Composition of Payroll Hours, Manufacturing Industries, 1962,* Bulletin 1428 (Bureau of Labor Statistics, April 1965).

[17] For a description of the Current Population Survey, see the *Handbook of Methods,* Bulletin 2490 (Bureau of Labor Statistics, April 1997), pp. 3–12.

[18] The Bureau of Economic Analysis has documented the estimating procedures underlying the input-output estimates. See, for example, *Definitions and Conventions of the 1972 Input-Output Study* (Bureau of Economic Analysis, U.S. Department of Commerce, July 1980).

[19] The cost of intermediates can be estimated as the residual, after labor and capital costs have been deducted from the value of gross output.

[20] This ideal nominal accounting structure is described in W. Gullickson and M. J. Harper, "Production Functions, Input-Output Tables, and the "Relationship Between Industry and Aggregate Productivity Measures" (Bureau of Labor Statistics, Office of Productivity and Technology, 1998).

[21] It should be noted that the Office of Employment Projections, as part of its growth model, prepares constant-dollar input-output tables as well as current-dollar tables. Presently, deflated tables are available for 1977, 1982, 1987, and 1992. The method used by the authors to estimate material inputs uses the current-dollar (undeflated) tables, together with price Törnqvist aggregation, to avoid index number bias.