

## Bias in aggregate productivity trends revisited

*Aggregate productivity trends were revised upward; it is now less clear whether bias exists, but some industries continue to show negative multifactor productivity trends*

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**T**his article updates results presented in our February 1999 *Monthly Labor Review* article, “Possible bias in aggregate productivity growth.”<sup>1</sup> In it, we determined that manufacturing could account for all of the multifactor productivity (MFP) growth during the 1979–96 period within the private business sector. The article identified industries outside of manufacturing with negative MFP trends and assessed their effects on aggregate productivity. We concluded that the negative MFP trends seemed at least somewhat implausible and might have reflected service output measurement problems.

This article reprises the methodology, summarizes the earlier findings, and presents new results. Besides including data through 1997, the new results reflect the comprehensive revisions of the National Income and Product Accounts published by the Bureau of Economic Analysis (BEA) in October 1999. Aggregate productivity now is growing faster, and it is less clear that there is an aggregate bias, but we still find negative MFP trends for some of the same industries. For other industries, we find surprisingly low MFP trends. This is probably indicative of problems with the measurement of some service industry outputs. It may also reflect the rapid growth in high tech inputs, such as computers and semiconductors, used by these industries.

### Outline of procedures

In the earlier article, we described the construc-

tion of estimates of MFP trends at both the industry and aggregate levels using available statistical agency data. MFP measures compare output trends with the trends in several inputs. A formal framework for MFP emerged from a 1957 paper by Robert Solow that discussed how to separate substitution among inputs from shifts in a production function.<sup>2</sup> MFP growth is designed to measure the joint influences on economic growth of numerous factors that people associate with productivity, such as technological change, efficiency improvements, returns to scale, and reallocation of resources. At the aggregate level, the principal inputs are labor and capital, while at the industry level, inputs also include materials and services purchased from other industries. Data are organized in a framework proposed by Evsey Domar in 1961.<sup>3</sup> Domar showed how data on the inputs and outputs of various industries that buy goods and services from one another can be used to measure industry MFP trends and to construct and account for aggregate MFP trends.<sup>4</sup>

### Earlier findings

In the earlier article, we carried out two main data exercises. One was a “top side” exercise, which showed that all of the private business MFP growth between 1979 and 1996 could be accounted for by MFP growth in manufacturing. This implied that the rest of the private business sector had no overall MFP growth.

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**Table 1.** Output per hour of all persons in major U.S. sectors, compound annual rates of change

Period	Business	Nonfarm business	Manufacturing
1947–2001 <sup>1</sup> .....	2.5	2.2	2.8
1947–60 <sup>1</sup> .....	3.3	2.7	2.0
1960–73 .....	3.3	3.0	3.0
1973–79 .....	1.3	1.2	2.2
1979–2001 .....	1.8	1.7	3.2
1979–90 .....	1.5	1.4	2.6
1990–95 .....	1.5	1.5	3.2
1995–2001 .....	2.6	2.4	4.1

<sup>1</sup> Data for manufacturing trends begin in 1949.

**Table 2.** Multifactor productivity trends in aggregate U.S. sectors

Period	Private business	Private nonfarm business	Manufacturing
1949–2000 .....	1.4	1.2	1.2
1949–73 .....	2.1	1.9	1.5
1973–79 .....	.6	.4	–.6
1979–90 .....	.5	.3	1.1
1990–95 .....	.6	.6	1.2
1995–99 .....	1.2	1.1	2.5
1995–2000 .....	1.4	1.2	<sup>1</sup>

<sup>1</sup> Data are not available for this industry during this period.

The second “industry exercise” constructed estimates of MFP trends at roughly the two-digit industry level. We identified the goal of determining which nonmanufacturing industries had negative MFP trends. After we identified industries with negative MFP trends, we sought to determine the extent to which each contributed to the relatively slow aggregate MFP trend. Working on the premise that *output* in these industries was measured with error, we simulated the adjustment of industry *output trends* enough to pull up the negative industry *MFP trends* to zero. This would have raised the aggregate MFP trend for 1979–92 by 0.44 percent.

In this earlier work, the industries with significant negative MFP trends, in order of their downward effects on aggregate MFP, were construction, insurance, banking, utilities, and health services. We argued that long-term negative MFP trends were implausible for these industries. We did consider some alternative measurement problems that might have led to negative MFP trends, but concluded that “...there is good reason to suspect that bias in output quantity/price (trend) allocation is a dominant explanation....”

## The new results

The tables accompanying this article correspond to the tables in the *earlier* article. Tables 1 and 2 present measures of output per hour and MFP, respectively, at the aggregate level. It has been widely noted that the 1999 BEA revisions raised the productivity trends. The size of the “raise” varied by period, but it was generally between 0.3 and 0.6 percent per year in various selected periods since 1979. The “raise” is attributable to three changes made by BEA: the introduction of “research CPIs [Consumer Price Indexes]” to the deflation process; the reclassification of software as capital; and the use of Bureau of Labor Statistics data on banking transactions in measuring banking output. The BEA revisions partially address the issues we raised in our *earlier* article. In the aggregate exercise worked out in the new table 3, now, we find nonmanufacturing contributing 0.5 percent per year to the business MFP trend between 1990 and 1995 and 0.6 percent during the 1995–99 period. These trends are up from zero in the earlier data presented in the *Monthly Labor Review*.

Turning to the “industry exercise,” first, our method develops what we call “BLS output based” MFP trends from input and output estimates for each industry.<sup>5</sup> We also develop what we call “BEA output based” MFP trends by adjusting the BLS MFP trends for consistency with the latest data on gross output from the BEA “gross product originating” program.<sup>6</sup> In the discussion here, we emphasize the “BEA output based” MFP trends.

The overall increase in the MFP trend appears to be supported by the revised “industry exercise,” summarized in table 4.<sup>7</sup> As in the earlier article, we caution readers that the data associated with our industry exercise (presented in tables 4, 6, and 7) should not be taken at face value. Rather, the point of the industry exercise is to help determine how weaknesses in economic statistics may affect the aggregate productivity picture. We compare one-digit industry data in the “new” table 4 with those in the “old” table 4 from the 1999 *Monthly Labor Review* article in the following tabulation, which estimates BEA and BLS based output trends:

*BEA output based MFP trends*

	<i>Old, 1977-92</i>	<i>New, 1977-97</i>
Farms .....	1.7	2.3
Mining .....	-1.5	-.8
Construction .....	-.9	-.9
Manufacturing .....	.7	.6
Transportation .....	.2	.2
Communications .....	.9	.1
Utilities .....	-1.1	-.1
Trade .....	1.2	1.1
Finance, insurance, and real estate .....	1.3	-.5
Services .....	.2	-.5

*BLS output based MFP trends*

	<i>Old, 1977-92</i>	<i>New, 1977-92</i>	<i>New, 1992-97</i>	<i>New, 1977-97</i>
Farms .....	1.8	2.1	1.3	1.9
Mining .....	-1.2	-1.7	1.2	-1.0
Construction .....	-.4	-.4	-1.0	-.6
Manufacturing .....	.5	.5	1.5	.7
Transportation .....	.4	.2	-.2	.1
Communications .....	.4	-.6	.7	-.3
Utilities .....	-.3	-.7	-.1	-.5
Trade .....	1.1	.9	.3	.7
Finance, insurance, and real estate .....	-1.2	-.4	-.4	-.4
Services .....	.1	0.0	-.6	-.2

In the first two columns, four of the ten sectors (farms, mining, utilities, and finance) have “BEA output based” MFP trends for 1977-97 that are between 0.6 and 1.0 percent per year higher than the trends for 1977-92 reported in the ear-

lier article. We might have expected the upward revisions to the aggregates to carry over broadly to the industry level—the BEA revisions tended to boost aggregate output trends and the extension of the time period to 1997 captures 2 years of the post-1995 productivity surge. In the final four columns of the tabulation, we use the more complete “BLS output based” data-set to examine the separate effects of revisions and extension of the time period. It is somewhat surprising to find MFP growing more slowly in five sectors during 1992-97 than it did during 1977-92. This is reminiscent of Robert Gordon’s finding that the productivity acceleration of the late 1990s is confined to a limited number of sectors.<sup>8</sup>

Perhaps more surprising is the observation that, in the first two columns, the “BEA output based” MFP trends for 1977-97 are 0.7 and 0.8 percent per year *lower* in two sectors, services and communications, than they were for 1977-92 in the old data. In the same vein, there were only small trend revisions (0.1 percent or 0 percent) for construction, manufacturing, transportation, and trade. MFP compares output trends with input trends, and it occurred to us that strong input growth may help account for some of these low MFP trends. The first three columns of table 5 break out the BLS MFP trends into output and input trends.

Services and communications have 4.5 percent input growth trends. High tech inputs (information processing equipment and software) contributed much of this input growth in communications, while their contribution was less noteworthy in services.<sup>9</sup> It is possible that there was overinvestment in communications. However, we suspect that the methods used to measure and price the outputs in communications fail to capture quality change to the same degree as do the methods used to measure and price the inputs they employ. We shall return to the high tech issue shortly.

As in the earlier study, table 6 contains estimates of the

**Table 3.** Multifactor productivity (MFP) growth in the U.S. private business sector and the contributions of labor composition effects, manufacturing MFP growth, and nonmanufacturing MFP growth

Period	Private business MFP (1)	Private business labor composition effects (2)	Unadjusted private business MFP (3)	Manufacturing MFP (4)	Contributions to private business of:	
					Manufacturing (5)	Non manufacturing (6)
1949-99 .....	1.4	0.2	1.6	1.2	0.6	1.0
1949-73 .....	2.1	.2	2.3	1.5	.8	1.5
1973-79 .....	.6	0	.6	-.6	-.3	.9
1979-90 .....	.5	.3	.8	1.1	.5	.3
1990-95 .....	.6	.4	1.0	1.2	.5	.5
1995-99 .....	1.2	.3	1.6	2.5	1.0	.6

**Table 4. Estimates of multifactor productivity trends in U.S. industries, selected periods**

[Compound annual growth rates of MFP]

SIC code	Industry	Main source of output estimates:			
		Bureau of Labor Statistics			Bureau of Economic Analysis
		1947-63	1963-77	1977-97	1977-97
1, 2	Farms .....	2.0	0.8	1.9	2.3
10-14	Mining .....	1.0	-1.4	-1.0	-.8
10	Metal mining .....	-	-1.3	2.1	2.0
11, 12	Coal mining .....	-	-1.9	3.0	2.9
13	Oil and gas extraction .....	-	-1.5	-2.2	-1.8
14	Nonmetallic minerals, excluding fuels .....	-	-.1	.5	.5
15-17	Construction .....	1.1	-1.1	-.6	-.9
20-39	Manufacturing .....	.8	.6	.7	.6
24, 25, 32-39	Durable manufacturing .....	.6	.7	1.1	1.1
20-23, 26-31	Nondurable manufacturing .....	.9	.5	.3	.2
40-47	Transportation .....	1.6	1.4	.1	.2
40	Railroad transportation .....	-	2.0	1.4	4.7
41	Local and interurban passenger transit .....	-	2.2	-.6	-1.5
42	Trucking and warehousing .....	-	.7	-.5	.6
44	Water transportation .....	-	1.1	.7	.9
45	Transportation by air .....	-	1.8	.4	.7
46	Pipelines, excluding natural gas .....	-	1.8	.1	-1.0
47	Transportation services .....	-	-.2	.1	0
48	Communications .....	3.2	2.4	-.3	.1
49	Electric, gas, sanitary services .....	3.5	.7	-.5	-.1
50-59	Trade .....	1.7	2.2	.7	1.1
50, 51	Wholesale trade .....	-	2.1	1.6	1.3
52-59	Retail trade .....	-	2.1	0	1.0
60-67	Finance, insurance, and real estate .....	.7	.6	-.4	-.5
60, 61, 67	Credit agencies, holding companies .....	-	.6	.1	-.5
62	Security, commodity brokers .....	-	-1.1	.3	1.5
63	Insurance carriers .....	-	1.5	-2.4	-.8
64	Insurance agents, brokers, and services .....	-	2.8	-1.1	-4.9
65-66	Real estate .....	-	.5	.1	.1
7-9, 70-89	Services .....	.4	-.6	-.2	-.5
7-9	Agricultural services, forestry, fishing .....	-	.3	1.1	.8
70	Hotels and other lodging places .....	-	.8	-2.2	-1.3
72	Personal services .....	-	1.5	.2	.6
73, 76	Business and miscellaneous repair services ....	-	-.7	-1.0	-1.0
75	Auto repair, services, and garages .....	-	-1.4	-.4	-1.4
78	Motion pictures .....	-	-1.0	.5	.4
79	Amusement and recreation services .....	-	-.1	.4	1.0
80	Health services .....	-	-1.7	-.6	-.6
81, 83-89	Legal and other professional services .....	-	-.5	1.0	-.2
82	Educational services .....	-	-.8	0	.8

contributions of each industry's productivity to private business MFP. These "Domar" contributions weight each industry's MFP trend by a ratio indicative of the industry's relative importance in the aggregate sector.<sup>10</sup> *If all of the underlying data were assumed to be correct, the Domar contributions would be the bona fide contributions of the industries*

*to aggregate productivity.*

Table 6 of the article shows results to the nearest 0.1 percent and shows only those industries that make nonzero contributions in at least one time period.<sup>11</sup> Some industries (construction; finance, insurance and real estate; and business services) make negative contributions. Thus, this would

**Table 5.** “BLS output based” trends in multifactor productivity (MFP), outputs and inputs, and the point contributions of specific input categories to the trend in input growth, 1977–97, annual rates

Sector	Trends			Point contributions to input growth			
	MFP	Output	Input	Information processing equipment and software	Other capital	Labor	Intermediate inputs
Farm .....	1.9	1.7	-0.2	0.02	-0.18	-0.16	0.14
Mining .....	-1.0	.3	1.3	.29	.41	-.29	.94
Construction .....	-.6	1.2	1.8	.05	-.03	.76	.98
Manufacturing .....	.7	2.5	1.8	.15	.18	-.01	1.50
Transportation .....	.1	2.9	2.8	.21	.15	.72	1.82
Communications .....	-.3	4.2	4.5	1.13	.68	.28	2.14
Utilities .....	-.5	.4	1.0	.45	.68	.14	.14
Trade .....	.7	3.1	2.4	.51	.49	.76	.91
Finance, insurance, and real estate .....	-.4	4.1	4.5	.39	.84	.73	2.32
Services .....	-.2	4.3	4.5	.30	.29	1.97	1.86

mean they appear to be pulling down aggregate MFP. MFP is designed to measure the effects of factors such as technology, efficiency, and returns to scale. For a growing industry, MFP is unlikely to decline over long time periods. Furthermore, we know that real output measurement is problematic in these sectors. These negative Domar contributions, therefore, may be symptomatic of measurement problems.

As noted in our earlier work, the Domar framework allocates some aggregate productivity growth to industries that sell some of their output to other industries. Except for sales of capital goods, these “intermediate” sales do not enter “final demand” in the National Income and Product Accounts, and are not counted in aggregate output. For that reason, any error in measuring the real output trends associated with these sales would not affect business sector productivity. Such an error would, however, lead to the wrong story on the industry allocation of productivity growth. Table 7 reports on “what if” simulations designed to isolate the effects of negative (and presumably incorrect) output trends on the aggregate productivity trends. The simulations, similar to those in our earlier work, estimate what would happen if we adjusted industry output trends enough to raise the MFP of all industries with negative measured MFP trends to zero (top panel) or to 1 percent (bottom panel).

We focus on the third column of the top panel of table 7, which shows the effects on raising negative “BEA output based” MFP trends to zero. The total effect is 0.34 on the trend for 1977–97. In our earlier work, the effect had been 0.44 on the trend for 1977–92. Furthermore, the same four industries contribute to the problem. Raising construction MFP to zero (by adjusting its output) would now increase the aggregate MFP trend by 0.12. This is followed by insurance

(0.08), health services (0.05), and banking (0.03). Negative MFP in auto repair also “contributes” .03.

A little discussion of banking is in order.<sup>12</sup> In our earlier work, we highlighted banking, which then had an MFP trend of -2.3 percent per year. At the time, the BEA banking output trends were measured, mainly, by using employment trends. This implied there was no change in labor productivity. In the 1999 National Income and Product Accounts revisions, BEA adopted the BLS banking output measures, which are based on counts of transactions. It now looks as if this change raised banking MFP almost enough to eliminate the negative MFP trend.<sup>13</sup> Banks have been investing heavily in capital, and the new output trends come much closer to accounting for the quality adjusted input growth. Still, the relative output and input trends give no indication of MFP *gains*.

### High tech equipment

In these new data, two unexpected results emerge: first, persistent and significant negative MFP trends in construction, insurance, health, and, to a lesser extent, banking; and second, lower MFP trends in services and communications than those apparent in the old data. These trends were surprising, because for this research, we have included data through the prosperous mid-1990s.

Earlier this year, Steve Oliner and Dan Sichel point out that high tech capital affects aggregate labor productivity growth twice: *first, when the capital is made and again, when it is used*.<sup>14</sup> As Solow showed in 1957, wherever capital input is *used*, it can contribute to labor productivity. As Domar showed in 1961, the industries where capital goods are *made* can experience productivity improvements and can contrib-

**Table 6.** Estimates of private business sector multifactor productivity and estimates of its attributions to industries, selected periods

SIC code	Estimated industry point contributions to private sector trends	Main source of output estimates:			
		Bureau of Labor Statistics			Bureau of Economic Analysis
		1947-63	1963-77	1977-97	1977-97
1, 2	Farms .....	0.3	0.1	0.1	0.1
10-14	Mining .....	.1	-.1	-.1	-.1
13	Oil and gas extraction .....	-	-.1	-.1	-.1
15-17	Construction .....	.2	-.2	-.1	-.1
20-39	Manufacturing .....	.7	.6	.6	.6
24, 25, 32-39	Durable manufacturing .....	.3	.4	.5	.5
20-23, 26-31	Nondurable manufacturing .....	.5	.2	.1	.1
40-47	Transportation .....	.1	.1	0	.1
48	Communications .....	.1	.1	0	0
49	Electric, gas, and sanitary services .....	.1	.1	0	0
50-59	Trade .....	.6	.7	.2	.3
50, 51	Wholesale trade .....	-	.3	.2	.2
52-59	Retail trade .....	-	.4	0	.2
60-67	Finance, insurance, and real estate .....	.1	.1	0	-.1
60, 61, 67	Credit agencies, holding companies .....	-	0	0	0
63	Insurance carriers .....	-	0	-.1	0
65-66	Real estate .....	-	.1	0	0
7-9, 70-89	Services .....	.1	-.1	-.1	-.2
73, 76	Business and professional services .....	-	0	-.1	-.1
80	Health services .....	-	-.1	0	0
81, 89	Legal and other professional services .....	-	0	.1	.0
	Total contributions: Private business trend derived by "Domar" aggregation .....	2.4	1.4	.7	.7
	<b>Private business sector MFP trend estimates</b> (compound annual rates of change):	<b>1948-63</b>	<b>1963-77</b>	<b>1977-97</b>	...
	Published BLS estimates .....	2.2	1.8	.6	...

Note: Industries and sectors with absolute contributions rounding to less than 0.1 in each time period have been omitted from table 6.

ute to aggregate productivity growth. We have estimates of each of these effects for high tech capital. In May 2001, BLS reported that increased “capital intensity” associated with the *use* of information processing equipment and software inputs accounted for 0.9 percent of the 2.6 percent labor productivity trend in private business during 1995–99. For this article, a new table shows the “Domar contributions” of two-digit manufacturing industries to the private business MFP trends.<sup>15</sup> (See table 8.) The striking result in table 8 is that SICs 35 and 36, where semiconductors and computers are *made*, account for about half of the 1.3 percent per year MFP trend for the entire private business sector during 1995–99 (and nearly three-fourths of the 2.5 percent trend of manufacturing MFP during the same period). Together, both high tech effects— manufacture and use—account for 1.6 percent

per year of the 2.6 percent labor productivity trend during 1995–99.<sup>16</sup> In other words, high tech capital appears to be the dominant explanation for productivity growth in the late 1990s.

These findings rest on estimated trends for high tech inputs and outputs that incorporate adjustments to account for changes in their quality.<sup>17</sup> Many of the high tech input and output growth rates are well up in the double-digit percentage range. These extraordinary trends, in turn, rest on the use of quality adjusted price indexes in deflation. These indicate that prices for high tech goods of constant quality have fallen very rapidly. These price trend estimates have withstood much scrutiny, but we must emphasize their importance for our conclusions. While it is likely that real output trends have been underestimated in many or all of the service sector industries

**Table 7.** Effects on aggregate MFP trends from adjusting output trends for those industries that exhibit negative MFP growth and also adjusting input trends for industries buying the outputs of the industries with negative MFP, 1977–97

SIC code	Industry adjusted and the total effects of the adjustment:	Bureau of Labor Statistics output-based:		Bureau of Economic Analysis output-based:	
		Private business multifactor productivity	Manufacturing multifactor productivity	Private business multifactor productivity	Manufacturing multifactor productivity
<b>Adjustments sufficient to produce zero industry MFP growth</b>					
	Total effects: .....	0.30	-0.14	<b>0.34</b>	-0.11
13	Oil and gas extraction .....	-.02	-.07	<b>-.01</b>	-.05
15–17	Construction .....	.08	0	<b>.12</b>	0
41	Local and interurban passenger transit .....	0	0	<b>.01</b>	0
42	Trucking and warehousing .....	.01	-.01	<b>0</b>	0
48	Communications .....	.01	0	<b>0</b>	0
49	Electric, gas, sanitary services .....	.03	-.02	<b>.01</b>	-.01
60, 61, 67	Credit agencies, and so forth .....	0	0	<b>.03</b>	0
63	Insurance carriers .....	.09	-.01	<b>.08</b>	0
70	Hotels and other lodging .....	.02	-.01	<b>.01</b>	0
73, 76	Business services .....	.01	-.03	<b>.01</b>	-.03
75	Auto repair, and so forth .....	.01	0	<b>.03</b>	-.01
80	Health services .....	.05	0	<b>.05</b>	0
<b>Adjustments sufficient to produce 1 percent industry MFP growth</b>					
	Total effects: .....	.68	-.27	.72	-.23
13	Oil and gas extraction .....	-.03	-.10	-.02	-.09
15–17	Construction .....	.21	0	.24	0
41	Local passenger transit .....	.01	0	.01	0
42	Trucking and warehousing .....	.02	-.03	0	0
48	Communications .....	.04	0	0	0
49	Electric, gas, sanitary services .....	.07	-.04	.06	-.03
60, 61, 67	Credit agencies, and so forth .....	0	0	.07	-.01
63	Insurance carriers .....	.14	-.01	.13	-.01
70	Hotels and other lodging .....	.02	-.01	.02	0
73, 76	Business services .....	.02	-.06	.02	-.06
75	Auto repair, and so forth .....	.04	-.01	.06	-.01
80	Health services .....	.12	0	.12	0

**Table 8. Contributions of manufacturing industries to private business multifactor productivity**

SIC code	Industry	1949-73	1973-79	1979-90	1990-95	1995-99
20	Food .....	0.09	0.01	0.03	0.05	-0.02
21	Tobacco .....	0	-0.01	-0.03	.02	-0.05
22	Textiles .....	.06	.06	.03	.02	.02
23	Apparel .....	.02	.04	.01	.01	.02
26	Paper .....	.03	-0.03	0	0	.03
27	Printing .....	.01	-0.02	-0.03	-0.04	-0.02
28	Chemicals .....	.11	-0.13	.04	-0.01	.04
29	Petroleum .....	.03	-0.03	-0.01	.01	.02
30	Rubber .....	.02	-0.04	.03	.03	.03
31	Leather .....	0	0	0	0	0
24	Lumber .....	.03	.01	.04	-0.02	-0.01
25	Furniture .....	.01	0	.01	.01	.01
32	Stone, clay and glass .....	.02	-0.03	.02	.01	.01
33	Primary metals .....	.02	-0.11	.01	.02	.04
34	Fabricated metals .....	.02	-0.05	.02	.03	0
35	Industrial and commercial machinery .....	.04	.01	.20	.16	.35
36	Electrical machinery .....	.08	.05	.13	.23	.34
37	Transportation equipment .....	.12	-0.05	.01	.03	.09
38	Instruments .....	.03	.03	.04	0	.02
39	Miscellaneous manufacturing .....	.02	-0.01	.01	0	.01
...	Total manufacturing contribution .....	.77	-0.32	.57	.55	.93
...	Private business sector multifactor productivity .....	2.10	.60	.50	.60	1.30

with negative MFP trends, it is also possible that the growth trends for high tech inputs have been overestimated. While either source of bias would tend to push service industry MFP trends down, the two would have opposite effects on the aggregate MFP trend. Underestimating service sector output trends would bias the aggregate productivity trend downward. Overestimating high tech input and output trends would bias the aggregate productivity trend upward.

With the results of this article, we can neither prove that service output growth rates are too low, nor determine that high tech input and output growth rates are too high. We can, however, express a concern that the “measurement playing field” may not be level. We have very intricate means of making quality adjustments to high tech goods, but we have few means to make quality adjustments to service outputs.

## Summary and conclusions

In our earlier work, the bottom line rested on aggregate productivity trends that were probably downward biased. In light of the new evidence presented here, reaching a firm conclusion about aggregate bias may be more difficult. Recent aggregate productivity trends are higher now than they were

when we published the earlier analysis. This is due to improvements made by BEA to the National Income and Product Accounts (affecting the aggregate productivity trends prior to 1995), and also to a significant speedup in productivity growth since 1995.

In spite of the measurement improvements, it is clear that the problem of “difficult to measure” service outputs has yet to be resolved. In the tables, most of the MFP anomalies noted in the earlier work remain, and several new ones have appeared. There are conceptual barriers to measuring the outputs of some service industries. Present methods probably still fail to capture many important quality improvements occurring in these industries. If, however, the growth in high tech capital quality is somewhat overstated, it would serve to confuse efforts to sort out where the productivity improvements really are and to assess the direction of any overall bias in the measured productivity growth rate.

Because many of the results in the “industry exercise” may reflect measurement problems, our ability to fully understand the sources of productivity change may be hampered. A need continues to exist for further scrutiny of the procedures for measuring price, output, and quality trends in ever-changing industries in both the service and technology sectors. □



## Notes

<sup>1</sup> This earlier article is available at <http://stats.bls.gov/opub/mlr/1999/02/art4full.pdf>.

<sup>2</sup> Solow, Robert M., "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, (1957) Vol. 39, No. 3, pp. 312-20.

<sup>3</sup> Evsey D. Domar, "On the Measurement of Technological Change," *Economic Journal*, December 1961, pp. 709-29.

<sup>4</sup> In an unpublished paper supplementing the earlier article, we described an "ideal" set of data and also a model that could use these data to calculate industry and aggregate productivity in a consistent manner. Ideally we would have (a) an annual set of nominal input-output tables defined consistently over time, (b) a complete set of price indexes for each product, and (c) complete data on real capital and labor inputs used by each industry. All of this would be consistent with published aggregate data on output and inputs. Of course, the available data fall short of this ideal. Construction of this data-set would be expensive, because it would involve reconciling considerable amounts of conflicting information and estimating much incomplete information. In the economic censuses, in Bureau of Economic Analysis input-output and National Income and Product Accounts work and in Bureau of Labor Statistics multifactor productivity (MFP) work, however, much of what would be needed to construct this ideal data-set is already effectively estimated. To get the results in the *Monthly Labor Review* article and the new results here, we have made assumptions and adjustments to reconcile various data with the framework we have in mind. By using many shortcuts, we have attempted to infer what MFP trends might emerge if the ideal data-set were really constructed.

The unpublished paper also spelled out the rationale for the model used in terms of production functions. We had this model and these "ideal" data in mind in formulating the industry exercise. It is important to be able to relate real economic growth measurement procedures to formal production theory. It is not the case that describing the link to theory forces a lot of assumptions onto the data. To the contrary, we are assuming much in any event, and careful links to theory help us understand what it is we are assuming, and by doing so, to guide the way to less rigid assumptions.

<sup>5</sup> On a quinquennial basis, we estimate a full set of inputs and outputs in both nominal and real terms. These are based in part on input-output tables and on industry gross output and output price series that the authors obtained from the BLS Office of Employment Projections (OEP). The OEP starts with Bureau of Economic Analysis benchmark input-output tables and makes adjustments for "time series consistency." At this point, the most recent benchmark table available is for 1992. The tables in the current paper reflect new OEP work that, in turn, reflects the 1999 comprehensive revisions to Bureau of Economic Analysis National Income and Product Accounts.

<sup>6</sup> This involves substituting the Bureau of Economic Analysis output trends for BLS output trends and using the input-output data to adjust the input trends estimates for compatibility with the Bureau of Economic Analysis output levels. Bureau of Economic Analysis-based trends are based on adjustments to BLS trends, and we never develop a full set of inputs and outputs consistent with Bureau of Economic Analysis-output based MFP trends.

<sup>7</sup> For those unfamiliar with the *Monthly Labor Review* article, we will note the major data sources used to estimate these MFP trends in table 4. These are the 1977 and 1992 input-output tables from the Bureau of Economic Analysis, adjustments to these tables for consistent definitions made by the BLS Office of Employment Projections (OEP), an estimate of the 1997 table made by the OEP and the authors using data from the 1997 Economic Censuses; Bureau of Economic Analysis data on nominal and

real gross output associated with their gross product originating measures; and data on capital and labor from the data-set supporting the published BLS MFP measures for the private business sector.

<sup>8</sup> Gordon, Robert J., "Does the New Economy Measure Up to the Great Inventions of the Past?" *Journal of Economic Perspectives* 14 (2000): pp. 49-74.

<sup>9</sup> To simplify processing, the "point contributions" of specific input categories to "input growth" were computed by multiplying each category's input quantity trend, for 1977-97, by the arithmetic mean of its cost shares in 1977 and 1997. Since the aggregate input growth trends are built up by chaining quinquennial trends, the sum of point contributions sometimes differs from the input growth rate by several tenths of a percent.

<sup>10</sup> The ratio is the nominal value of the industry's sectoral output divided by the nominal value of private business gross product originating. The contribution of industries to aggregate productivity growth by Domar's method is independent of the form of the MFP measures used for each. Industry measures can be alternatively based on gross output, "sectoral output," or a net value-added output and, as long as the nominal values used for weights and the inputs and outputs underlying the MFP measure are defined consistently, industrial contributions are unaffected. The term "sectoral output" is attributable to Frank Gollop. It expresses Domar's preferred concept of an industry's output: it includes all sales to final demand plus all sales to other industries, but deducts from that the value of intermediate inputs purchased from within the industry in question. Note that the scope of the measure depends on the degree of aggregation: as we examine progressively more aggregate industrial sectors, successively more intermediate inputs are excluded. As we noted in our *Monthly Labor Review* article, the sum of these ratios is more than one because the industries sell intermediate products to one another. The intuition as to why the weights would add up to more than one can be illustrated by the following example. If the productivity of steel makers improved by 1 percent, and the productivity of automakers improved by 1 percent, then the productivity with which the economy created cars would have increased by more than 1 percent.

<sup>11</sup> When contributions are added up (with more precision than shown), these new calculations approximately replicate the published MFP trends for the private business sector (compared in two lines near the bottom of the table). For 1977-97 the new detailed contributions are consistent with an aggregate MFP trend of 0.7.

<sup>12</sup> Note that the category we refer to as "banks" includes private, for-profit financial institutions within SICs 60, 61, and 67. Among the more important types of institutions in these industries are commercial banks, savings and loans, credit agencies, bank holding companies, certain trusts, and royalty administrators. Commercial banks accounted for about 57 percent of the employment in this category in 1995.

<sup>13</sup> In table 4, the trend is -1.6 percent per year from 1977-97. We also calculated the trend for 1987-97 and this was -0.8 percent per year.

<sup>14</sup> Oliner, Stephen D. and Daniel E. Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic Perspectives*, Fall 2000, pp. 3-22.

<sup>15</sup> These results are based on MFP trends that BLS publishes, and so they are not subject to quite so many qualifications as the nonmanufacturing estimates.

<sup>16</sup> Oliner and Sichel found similarly large effects from both the making and the use of high tech items.

<sup>17</sup> Both of Oliner and Sichel's effects are directly dependent on the measured growth rate of high tech quality change.