The Early 21st Century U.S. Productivity Expansion is *Still* in Services

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Abstract

Labour productivity in the U.S. non-farm business sector grew two and a half per cent per year during the 1995-2005 period, nearly double its growth rate over the previous two decades. Services sector labour productivity (LP) and multifactor productivity (MFP) grew more rapidly and substantially exceeded productivity accelerations in the goods sector. We show that the services sector accounted for three-quarters of U.S. MFP growth after 1995, and within services the contribution of MFP to LP growth exceeded the vaunted contribution of IT investment. We also find that the services sector has become even more important as the primary source of sustained productivity growth after 2000.

In this study, we compute LP, MFP and contributions to growth accounts for 57 industries within the goods and services sectors, using the new NAICS-based data set. We also show that resource reallocations, which are a newly important factor in productivity analysis, have changed the relation between increases in industry productivity growth rates and aggregate and sector growth rates in surprising ways.

Introduction and Summary

THE 20TH CENTURY ENDED WITH an unexpected surge in U.S. productivity growth. Labour productivity (LP) in the non-farm business sector grew two and a half per cent per year during 1995-2000, nearly double its growth rate over the previous two decades. In the opening years of the 21st century, Bureau of Labor Statistics estimates show that labour productivity has grown at three per cent per year, and somewhat less in the data we use for this article.

In Triplett and Bosworth (2006), Bosworth and Triplett (2007) and Triplett and Bosworth (2004),[2] we advanced an interpretation of the post-1995 U.S. productivity expansion that differed from the findings of other researchers (e.g. Oliner and Sichel, 2000; Jorgenson, Ho and Stiroh, 2000; and Gordon, 2000). Earlier studies focused on impressive multifactor productivity (MFP) growth in computer and semiconductor production, its resulting feedback into information technology (IT) investment in the rest of

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2 These studies are cited in the order written, which is of course, not the order published — our last work was published well in advance of the two conference volumes.

Table 1
Comparison of BEA/BLS and BLS Non-farm Business Labour Productivity, 1987-2005
(average annual per cent change)

Component	1987-95	1995-2000	2000-05
Output per hour			
BEA/BLS dataset	1.4	2.5	2.5
BLS	1.5	2.5	3.1
Output			
BEA/BLS dataset	3.0	4.8	2.4
BLS	3.0	4.7	2.6
Hours			
BEA/BLS dataset	1.6	2.3	-0.1
BLS	1.5	2.1	-0.5
Employment			
BEA/BLS dataset	1.7	2.5	0.2
BLS	1.5	2.2	-0.1

Source: Computed by authors as explained in text.

the economy, and the subsequent labour productivity (LP) growth in "IT-using" industries because of IT capital deepening.[3]

Unlike previous researchers, we examined productivity in services industries. We showed that strong MFP growth in the services sector transformed American economic performance after 1995. During the years of slow aggregate productivity growth (1973-1995), the services industries were marked by productivity stagnation in both LP and MFP, as Griliches (1992, 1994) pointed out. After 1995, services productivity accelerated strongly. In the revised Bureau of Economic Analysis/Bureau of Labor Statistics (BEA/BLS) data used for this article, services sector LP and MFP growth rates more than doubled after 1995. The acceleration of services sector LP substantially exceeded the more modest productivity acceleration in the goods sector.[4]

Strong services sector MFP growth is real news — and significant news. The services sector contributed three-quarters of the economy-wide acceleration in MFP after 1995, a contribution that is without historical precedent. Moreover, within services the contribution of MFP to LP growth exceeded the vaunted contribution of IT investment: More than half of the newly robust services sector LP growth came from the post-1995 acceleration of MFP growth.

Our results — that the services sector became the source of economic growth in the U.S. after 1995 — spawned a subsequent research topic: Why did European countries, and to a lesser extent Canada, not experience similar services-industries productivity growth?[5]

Confounding the predictions of some economists, U.S. productivity continued to advance in the new century, even though the late-90s IT investment boom ended and despite the recession of 2001. In this article, we extend our industries-

3 In this article, IT investment follows the BEA definition of information processing equipment and software: computer and peripheral equipment, software, and other information processing equipment (which includes communications equipment, instruments, copying machines and so forth). In 2005, software (43 per cent of IT investment) and other (38 per cent) were the largest categories, computer and peripheral equipment (19 per cent) the smallest. Though some economists use the term "ICT," we find it not a very descriptive acronym for the content of information processing equipment.

4 For this article, "goods sector industries" include manufacturing, mining and construction. "Services sector industries" include all other industries in the non-farm business economy, as defined by BLS and BEA. Government, of course, is not included. The BLS definition excludes non-profit organizations from the business economy, but BEA's industry data do not; the most important implication is that the medical care and education industries in our dataset include nonprofit hospitals, universities and so forth, but the industry definitions do not include government hospitals, for example, nor government primary and secondary education. The BLS non-farm business sector includes commercial real estate while our dataset excludes commercial real estate.

5 See, for example, O'Mahony and Van Ark (2003) and Inklaar and Timmer (2006). A subtopic grew out of this, mainly in the European policy-making setting: Is differential U.S.-E.U. services industry growth biased or illusionary because of differences in data across countries? The answer seems to be "no" (Inklaar and Timmer, 2006), though the stage of data development for industry productivity analysis differs greatly among OECD countries.

based approach to consider the post-2000 period. We find that the services sector has also maintained strong productivity growth in the post-2000 period. Late 20th century and early 21st century labour productivity growth was driven both by accelerating MFP growth in services and capital deepening. Labour productivity growth in the two periods thus has similar sources, and the second productivity advance is just an extension of the first.

On the other hand, *at the industry level* the picture has become more complex. Aggregation of industry productivities into sector and economy-wide levels requires allowances for resource reallocations. Productivity has greatly increased in services industries, but in recent years reallocation effects have been large and variable within the sector. For this reason, changes in productivity at the sector and aggregate levels differ from aggregated productivity change at the *industry* level. Reallocations are a new factor in the analysis of productivity growth.

Late 20th and Early 21st Century Productivity Expansions

Data

Recently, the Bureau of Economic Analysis has substantially improved its methodology for constructing its industry dataset, revised the data, and introduced the North American Industry Classification System (NAICS) to replace the old SIC system (Moyer *et al.*, 2004; Moyer, Reinsdorf and Yuscavage, 2006). These improvements, which incorporate improvements in the basic source data from the Bureau of Labor Statistics and the Census Bureau, add to earlier improvements (Lum, Moyer, and Yuscavage, 2000), and have transformed the U.S. industrial database to make it more useful for economic analysis than was in the past. The industry classification changes and the pertinent data revisions have been introduced into the BLS capital services measures, which provide the capital input measures for our MFP computations. Our data set covers 57 industries for the period 1987-2005.

Our estimates of labour productivity for the aggregate of non-farm business differ somewhat from the published BLS series. The two measures differ because the BEA industry data set includes nonprofit enterprises, which are excluded from the BLS measure. More important are some problems matching the employment data produced by BLS with the industry output measures, which are largely based on data originally collected by the Census Bureau. Differences in the industrial classification of enterprises between the business lists of Census and BLS raise concerns about the industry comparability of the data on employment and output. These concerns have been heightened by the different processes used by the agencies to convert the historical data to the new NAICS.

Previously, we relied on a measure of full-time equivalent employees plus the self-employed that was produced by the BEA. We believed it to be most consistent with the output data of the BEA and were distrustful of the industry-level data on hours worked. However, the BEA limited its conversion of the employment data prior to 1998 to a single series on the total number of employees. In addition, there are some problems with the post-1998 data on the self-employed and full-time equivalents that are yet to be resolved.

Alternatively, the Office of Employment Projections (OEP) of the BLS has produced estimates of employees, the self-employed and total hours for the earlier years, but these estimates have not yet been updated to 2005. We also noted that there are substantial differences in the number of employees for some industries as reported by the two agencies (Triplett and

Table 2
Productivity Growth in Non-farm Business, Goods, and Services Sectors, 1987-2005
(directly measured, average annual rate of change)

	1987-95	1995-00	2000-05
Labour Productivity			
Non-farm Business	1.4	2.5	2.5
Goods Sector	2.4	3.0	2.9
Services Sector	1.1	2.3	2.4
Multifactor Productivity			
Non-farm Business	0.9	1.6	1.7
Goods Sector	1.8	2.3	1.9
Services Sector	0.5	1.3	1.5

Source: Computed by the authors from the new NAICS-based industry data set, December 2006 release.

Bosworth, 2007). Thus, we opted to use the basic employee estimates of BEA multiplied by the ratio of total hours to employees for each industry from the BLS OEP. We held the estimate of hours per employee constant between 2004 and 2005.

As noted in the introduction, the data inconsistencies do create a discrepancy in the measures of labour productivity at the aggregate level of the non-farm business sector. These differences are documented in Table 1 for the interval of 1987 to 2005. While the differences are inconsequential in the early years, they are more significant for the 2000-05 period where our measure of output per hour rises at 2.5 per cent per year compared to 3.1 per cent for the published BLS measure. Most of this difference arises from a faster rate of growth in the labour input measure in our industry data set. The differences in LP growth are persistent over the five years, but they result from significant differences in employment growth in 2000-03 and 2005, and differences in output growth over the last two years. The BEA estimates of employment growth show a smaller decline in the 2001-02 recession and a larger increase in 2005. Coincidentally or not, the latest difference seems consistent with the recent benchmark adjustment to the BLS employment estimate.

On the other hand, the two series show similar short-run trends. Through 2004, they both indicated that post-2000 LP growth exceeded growth in 1995-2000, and they both record slowdowns since 2004. The latest BLS release (March 6, 2007) reports non-farm business sector LP growth of 2.1 per cent for 2005 and 1.6 per cent for 2006.

Productivity change in the 1995-2000 period

We first use the revised BEA-BLS data to re-estimate the productivity change analysis for the pre- and post-1995 periods covered in our book (Triplett and Bosworth, 2004). Our major finding — that productivity growth in the services sector accelerated much more after 1995 than productivity in the goods sector — is confirmed, even though revisions and the changes incorporated in the shift to NAICS have changed the magnitudes of the estimates considerably.[6]

Private non-farm productivity growth nearly doubled in 1995-2000 compared to 1987-95 (Table 2). Part of this development originated in the goods sector, where LP and MFP growth accelerated by about 30 per cent. More importantly, the growth rate of services sector LP and MFP more than doubled. This dramatic change in the services sector drove most of the famed revival of U.S. productivity growth.

At the sector level, data revisions, methodological improvements, and classification changes raised LP and MFP growth rates in the goods sector and lowered both the productivity growth rates and the magnitude of acceleration in the services sector. In the revised data, services sector productivity grew more slowly over

6 For our book (Triplett and Bosworth, 2004), data were only available through 2001. We now use the year 2000 as the break year, a more natural end point than 2001, which was a recession year. The results do not depend on the break year.

1995-2000 than the productivity of goods sector industries, but services were clearly catching up.[7] Since the services sector was by far the lagging sector in the pre-1995 period, its emergence as a contributor to productivity advance — particularly to MFP growth — was the most striking aspect of the post-1995 era. The extraordinary acceleration of services sector productivity has been too little noted and too much neglected.

Productivity change in the early 21st century — the aggregate and sector data

Defying many predictions, aggregate U.S. LP continued to advance after the recovery from the 2001 recession. The much-discussed second round of acceleration that some researchers detected in the BLS measure is less evident in the industry dataset. However, it shows that non-farm LP has advanced in the opening five years of the 21st century at the same rapid rate as in the last five years of the 20th century — 2.5 per cent per year. We calculate that aggregate MFP growth has held up as well, at 1.7 per cent per year, a healthy rate for an advanced economy.

The aggregated sectoral data in Table 2 indicate that U.S. productivity growth in the early 21st century has again taken place largely in the services sector, as it did in the closing years of the 20th century. Indeed, goods sector LP and MFP growth both declined after 2000. Services sector LP and MFP, on the other hand, continued to accelerate after 2000, to 2.4 per cent per year for LP and 1.5 per cent for MFP. The post-2000 services sector MFP acceleration is not as dramatic as in 1995-2000, but still its post-2000 growth is three times its pre-1995 growth rate. Non-farm business LP and MFP growth rates have held up in the face of declines in the goods sector rates because the services sector has made up the gap.

Services sector productivity growth rates still lag those of the goods sector, but the rates are converging. In the early 21st century, services sector LP and MFP are about 80 per cent of the corresponding rates for the goods sector. In the pre-1995 period, services productivity growth rates were from two-fifths (LP) to only one-quarter (MFP) of the goods productivity rates. For the services sector to have approached near parity in such a short time is one of the most remarkable — and overlooked — economic transformations of any era.

Sources of Productivity Growth

Sector level analysis

We use standard growth accounting methodology to decompose aggregate, sector, and industry LP growth into contributions from capital services, partitioned into IT capital services and other capital services, and from MFP (and for industry estimates, intermediate inputs). Our sectoral estimates are found in Table 3. We discuss our industry estimates later.

In the years 1995-2000, the United States experienced an investment boom, most of which was IT investment. Not surprisingly, then, nearly all of the capital contribution to non-farm LP growth during this period came from IT capital, as IT investment doubled its contribution to LP, compared to 1987-1995 (its contribution went from 0.4 to 0.8 points — see upper panel of Table 3). The IT contribution increased in both goods and services sectors by comparable amounts, but in the services sector, IT made up a larger part of the total capital contribution (nearly all — lower panels of Table 3).[8]

7 Earlier data suggested that services sector productivity growth exceeded that of the goods sector. The revised data show this is not yet the case. Classification changes account for part of the revision to the goods/services growth ratio.

Table 3
Non-farm Business, Goods, and Services Sector Labour Productivity Growth and Contributions, 1987-2005
(average annual per cent or percentage point change)

	1987-95	1995-00	2000-05
Non-farm Business			
Labour productivity	1.4	2.5	2.5
Capital contribution	0.5	0.9	0.8
of which: IT	0.4	0.8	0.5
Multifactor Productivity	0.9	1.6	1.7
of which: Computers	0.3	0.7	0.3
of which: Services	0.3	0.9	1.1
Goods sector			
Labour productivity	2.4	3.0	2.9
Capital contribution	0.5	0.7	0.9
Of which: IT	0.3	0.5	0.3
Multifactor Productivity	1.8	2.3	1.9
Services sector			
Labour productivity	1.1	2.3	2.4
Capital contribution	0.6	1.1	0.9
of which: IT	0.5	1.0	0.6
Multifactor Productivity	0.5	1.3	1.5

Source: Computed by the authors from the new NAICS-based industry data set, December 2006 release.

The capital contribution to non-farm business sector LP growth in 2000-2005 is nearly the same as in 1995-2000. However, the composition of investment changed after 2000. The IT boom ended and as others have observed, non-IT investment picked up some of the slack.[9] This was especially true for the goods industries, where the IT contribution fell in half, but where the overall capital contribution rose. In the services industries, the IT contribution also fell, as did the overall capital contribution, though only by 0.2 points.

Increasing IT investment in 1995-2000 has been well documented. But if IT boomed, MFP in services boomed even more.

Within the services sector, the MFP contribution to services LP, at 0.5 points previously, rose to 1.3 points in 1995-2000 (Table 3). MFP made an even larger contribution to services LP growth than provided by IT (1.0 points).

Not surprisingly, given the importance of services in the non-farm economy, the strong contribution of services MFP carried over to non-farm LP. Services MFP contributed more than a third of non-farm LP growth (0.9 points of the 2.5 per cent per year non-farm LP growth), about the same as the contribution to LP growth made by MFP in the production of computers.

Much of the recent productivity literature has examined accelerations, that is, the determinants of the increase in LP growth from 1.4 per cent per year before 1995 to 2.5 per cent after. Accelerations in growth contributions can be computed by reading across the rows in Table 3. Accelerating services sector MFP growth after 1995 contributed about the same to the LP acceleration as the much more widely acclaimed acceleration of MFP in IT: both contributed 0.5 points of the 1.1 point acceleration.[10] By this metric, as in others, MFP in services was a striking component to the advance in U.S. LP growth after 1995.

Turning now to the early 21st century expansion (right hand column of Table 3), all of the

8 Revised data have not changed the aggregate picture for 1995-2000, but they have changed the allocations between goods and services. Goods sector LP has been revised up sharply, and services LP revised down, but less so (services LP growth is now estimated at 2.3 per cent for the 1995-2000 interval, it was 2.6 per cent in the old data). The capital contribution has been revised down marginally in both sectors, but the IT portion has been revised up. In the new data, IT contributes relatively more to services LP than it did in the old data, and MFP contributes less. Compared to the new estimates for 1995-2000 in Table 3 (1.0 and 1.3 percentage points, for services sector IT and MFP contributions), the old were estimates were 1.0 and 1.5, respectively (Triplett and Bosworth, 2004, Table A-2, page 346).

9 The growth in capital intensity after 2000 also reflects the virtual disappearance of growth in employment.

10 The total acceleration from accelerating components exceeds 100 per cent, because there are components that decelerated. Thus, there is nothing inconsistent in the fact that the contributions of services MFP, IT MFP, and IT capital deepening add to more than the total acceleration.

modest increase in non-farm MFP, post-2000, took place in the services sector, where MFP continued to accelerate, though by a lesser amount (0.2 points, from 1.3 to 1.5 per cent per year). Moreover, growth in the MFP contribution, especially from services MFP, continued to drive non-farm LP growth after 2000. Indeed, services MFP advance was the sole source that supported aggregate LP growth. Every other contributor to non-farm business LP growth made a smaller contribution after 2000.

Judging from the aggregate and sector data, continued U.S. productivity growth in the post-2000 period is no surprise; it is just as an extension of the trends we described for the 1995-2000 period. Services sector MFP acceleration and economy-wide capital deepening continue to drive the non-farm business LP advance. The main difference in the early 21st century is the changed composition of investment — more contribution from non-IT investment — since the size of the total capital contribution remains nearly as high as it was at the end of the 20th century (and substantially greater than what it was before 1995).

Others who have contended that the late 20th and early 21st century productivity expansions were different have overlooked strong services sector productivity growth, the tie that binds them together. In particular, they have focused on the declining IT contribution after 2000. But as we have shown, though IT was a large contributor to LP acceleration after 1995, it was not the only one. Services MFP was also a major factor, and services MFP is the sole contributor to growth that held up and even accelerated after 2000. Overemphasis of the IT effect carries into economic analysis the "dot com" overemphasis from the period before 2000. IT is important. But it is not the only factor that is important. Crucially, IT is not the major contributor to recent productivity advance; MFP in services is.

Industry productivity growth rates and resource reallocations

Tables 2 and 3 show *direct* productivity measures — we aggregate value added to the sector and aggregate levels and then divide by the appropriate (aggregated) input concept. These tables do not show aggregated *industry* productivity growth rates.

We also compute industry productivity measures for LP and for MFP, for 24 goods industries and 33 services industries, using gross output in the numerator, rather than value added.[11] Indeed, we compute growth accounts for each of these 57 industries according to equation (1). This permits us to analyze productivity performance within sectors and across industries. We use gross output in our industry growth equations because value added implies very stringent conditions on the structure of production that have been decisively rejected empirically (for example, Berndt and Wood, 1975).

$$(1)\quad \Delta \ln LP = s_{K_{IT}} \Delta \ln(K_{IT} / L) + s_{K_N} \Delta \ln(K_N / L) + s_M \Delta \ln(M / L) + \Delta \ln MFP$$

Within this model , capital services, K, are disaggregated into IT capital (K_{IT}) and non-IT capital (K_N), intermediate inputs — combined energy, materials, and purchased services — are designated as M, and the *s*'s denote two-period averages of the input shares.

We aggregate industry LP and MFP measures to goods and services sector levels and to the aggregate level. For the aggregation of industry LP growth measures, we use Stiroh's (2002) system:

11 The old BEA dataset had 25 goods industries and 29 services industries. Triplett and Bosworth (2004, Appendix Tables A-1 and A-2) present industry productivity results for these industries. Some activities (publishing, for example) were transferred across sectors in NAICS, so the goods-services boundary is not the same in the new and old data, and the BEA list of services industries differs appreciably.

$$(2)\quad d\ln LP^V = \left[\sum_i w_i d\ln LP_i^Q\right] + \left[\sum_i w_i d\ln L_i - d\ln L\right] + \left[\sum_i m_i (d\ln Q_i - d\ln M_i)\right]$$

where

LP^V = aggregate value added per worker,

LP_i^Q = gross output per worker in industry i,

w_i = the two-period average of the share of industry i's nominal value-added in aggregate value-added, and

m_i = The two-period average of the ratio of industry i's nominal purchased inputs to aggregate value-added,

and of course, K, L, and M are the standard notations for capital, labour and intermediate inputs.

For the aggregation of MFP change, we use the generalization of the Domar weighting system presented in Jorgenson, Gollop and Fraumeni (1987):

$$(3)\quad d\ln MFP^V = \left[\sum_i v_i d\ln MFP_i^Q\right] + \left[\sum_i v_i s_i^k d\ln K_i - \bar{s}^k d\ln K\right] + \left[\sum_i v_i s_i^l d\ln L_i - \bar{s}^l d\ln L\right]$$

where

v_i = two-period average of the ratio of industry i's gross output to aggregate value-added (Domar weights), and

s_i = the two-period average share in industry i of the designated factor's (K or L) income in nominal gross output,

MFP^V is aggregate MFP (computed on value added),

MFP_i^Q is industry MFP, for industry i, using gross output,

and other variables are defined in equation (2).

As the equations show, the direct non-farm and sector productivity measures discussed in the previous section reflect two forces — the effects of weighted changes in industry productivities and the effects of reallocations among industries. For the LP case in equation (2), the first term on the right-hand side are weighted industry LP estimates. The second and third terms measure inter-industry shifts in labour and intermediate materials usages, respectively. Note that the second term is the weighted average of industry labour input *growth* relative to overall labour input growth, and similarly for the intermediate inputs term.

Interpretations of the reallocation terms are not immediately intuitive. Consider a technological shock in industry A that raises MFP and thereby LP, and for the sake of the illustration we specify that technologies in other industries are unchanged. Unless the demand elasticity for industry A's output is high, industry A will use fewer resources. If the released resources go to industries with lower productivity growth rates, the reallocation reduces aggregate and sector productivity rates (the direct rates). Reallocations thus provide a partial offset to the direct impact on the sector rates from industry A's productivity gain.[12]

Reallocation effects have been large in recent years, and have changed signs from one period to the next. They have thus shifted the relation between aggregate and industry productivity growth in unpredictable ways. Our estimates are in Table 4.

Begin with the top panel of Table 4, which pertains to the non-farm business economy. The top line records the aggregation of LP growth in the 57 industries in our dataset, where individual industry LPs are aggregated using value added weights — the first term of equation (2). Aggre-

12 This is not an index number problem. We weight industry productivities with the 2-period average of value added. The reallocation problem concerns reallocations of inputs, not of the value added that serves as the weights.

gated industry LPs grew 1.9 per cent per year in the 1987-95 period, rising to 3.4 per cent in 1995-2000, then falling back to 2.5 per cent in 2000-2005. If industries roughly correspond to production functions, and ignoring the well-known non-technological factors that shift MFP,[13] the aggregated industry LP growth rate provides an estimate of the aggregated combinations of factor substitutions and technological shifts on LPs in the 57 industries.

The second and third lines of Table 4 show reallocations of labour and intermediate inputs, the second and third terms of equation (2). Subtracting the reallocations from the first line gives in the fourth line the direct sector productivity rates from Table 3. For the direct rates, aggregated value added is divided by aggregated labour.

Reallocations have typically reduced the direct productivity rates. For example, in the 1995-2000 period both reallocation terms had negative impacts. Together, they reduced aggregate LP growth by 0.9 points. During 1995-2000, the LP growth of industries in the non-farm economy expanded considerably faster than did aggregate non-farm LP growth.

Nearly all of the discussion of post-1995 LP growth in the U.S. has put that growth at 2.5 per cent per year (Table 2); yet, technological change and factor substitution at the industry level actually raised LP growth by 3.4 per cent per year in the 1995-2000 interval. Productivity at the industry level (which is where the productivity paradigm makes the most sense) was growing even faster than the aggregate number that received so much attention.

Similar calculations for sector productivity are presented in Table 4. These reallocations again use equation 2, but applied only within the sector (the reallocations within sectors do not add to total reallocations, because the latter include also reallocations between the sectors). At the sector level as well, the aggregated industry rates for 1995-2000 were substantially higher than the direct sector rates because the reallocations terms subtract from the aggregated industry LP growth rates. For example, aggregated LP in the services industries grew 3.5 per cent per year during 1995-2000, nearly double the pre-1995 rate, but services sector LP grew only 2.3 per cent per year.

Few productivity researchers have paid attention to resource reallocation effects.[14] For the question that most economists were exploring — how much did productivity improve after 1995? — reallocations did not matter. Using either the direct rates or the aggregated industry

Table 4
Labour Productivity by Sector and Reallocations, 1987-2005
(average annual per cent change)

	1987-95	1995-2000	2000-05
Non-farm business (aggregated)	1.9	3.4	2.5
Labour reallocation	-0.3	-0.1	-0.4
Intermediate input reallocations	-0.2	-0.8	0.4
Non-farm business (direct calculation)	1.4	2.5	2.5
Aggregated goods industries	2.3	3.2	2.2
Labour reallocation	-0.1	-0.3	-0.1
Intermediate input reallocations	0.2	0.1	0.7
Goods sector (direct calculation)	2.4	3.0	2.9
Aggregated services industries	1.8	3.5	2.7
Labour reallocation	-0.3	0.1	-0.5
Intermediate input reallocations	-0.4	-1.2	0.2
Services sector (direct calculation)	1.1	2.3	2.4

Source: Computed by the authors from the new NAICS-based industry data set, December 2006 release.

13 MFP is famously a residual. It can change with, in addition to technological shifts, measurement errors in outputs and inputs and changes in omitted variables, particularly intangibles and the coinvestments considered in much of the computer impact literature. See, among the large number of references that could be cited, Corrado *et al.* (2005) and Brynjolfsson and Hitt (2000).

14 An exception is Stiroh (2002, 2006).

rates, LP growth roughly doubled after 1995, and the post-1995 accelerations in the goods and services sectors were likewise similar. That reallocations reduced the sector and aggregate rates well below the industry rates was an intriguing curiosity, but one that suggested little of interest for the analysis of productivity growth.

In contrast, reallocations do matter for the most recent period. Net reallocations, a large negative number before 2000, were nil at the economy-wide level over 2000-2005. Substantial declines occurred in the industry LP rates, which fell from 3.4 to 2.5 per cent per year. But reallocations in 2000-2005 subtracted much less from the industry rates than they had earlier. Indeed, the decline in the magnitudes of the reallocation terms after 2000 coincidentally equaled the decline in the aggregated industry productivity rates, and left (as we noted earlier) the non-farm direct LP rate constant (at 2.5 per cent). Comparing 2000-2005 with 1995-2000, the direct non-farm LP growth rate held up, even as the aggregated industry LP growth rates declined from 3.4 per cent to 2.5 per cent, annually.[15]

The same was true of direct sector and aggregated industries rates in goods and services taken separately. In both cases, the direct sector rates held up after 2000 even as the aggregated industries LP growth rates fell because in both sectors the reallocation terms became less negative. Indeed, in the goods sector reallocations turned positive, led by strong positive intermediate materials reallocations, and boosted the direct LP growth rate (2.9 per cent) above the aggregated industries LP rates (2.2 per cent). To our knowledge, this is the first time net reallocations have been positive for any sector. In services, the decline in reallocations turned a decline in the industries' LP growth rates (of 0.8 points) into an increase of 0.1 point in the direct LP growth rate.

Shifts in reallocation terms interject a perplexing new variable into the analysis of post-2000 productivity growth. One can ask: have U.S. LP growth rates held up since 2000? The industry rates indicate that the answer to that is negative, for industry LP growth rates have fallen from 3.4 per cent to 2.5 per cent per year. But the direct rate has been maintained at 2.5 per cent, because the reallocations across industries have become less negative. In the early years of the 21st century, the U.S. economy is no longer shifting resources, as it did in previous times, toward the industries that have lower productivity growth.

Similar questions about goods and services sectors yield similar answers. As we have noted earlier, when measured by direct productivity rates, services sector LP growth accelerated slightly after 2000 (from 2.3 to 2.4 per cent per year), and goods sector LP growth decreased imperceptibly (from 3.0 to 2.9 per cent). However, aggregating the goods industries' and services industries' LP growth rates, we find (Table 3) that they both fell, compared to end of the 20th century rates. Goods industries' LP growth rates dropped more (from 3.2 to 2.2 per cent), but services industries' LPs also fell (from 3.5 to 2.7 per cent).

Interpretation

The sustainability of recent U.S. productivity performance is a question of great current interest. Much of the analysis of sustainability has employed reasoning that draws on the factor substitution contribution to LP growth (for example, through IT capital deepening), and secondarily on technical change at the industry level. But since resource reallocations have recently made substantial, and fluctuating, contributions to sector and aggregate productivity growth, reallocations are a third factor that must be brought into consideration.

More favorable reallocation effects may also be part of the complex of favorable circum-

15 Note that aggregation of the industry productivity rates (equals 2.5 per cent) equals the direct rate, because reallocations net out in 2000-2005. This was not the case earlier.

stances that the U.S. economy enjoyed in recent years. Denison (1962) emphasized the shift of laboor out of (then) low productivity agriculture as a force for improving U.S. productivity. The United States may have returned to a period where resource shifts play once again a positive role in U.S. productivity growth. But this, as with much discussion of productivity prospects that others have entertained, is speculative.

Because so little attention has been paid to reallocation effects, it is worth noting that BEA data and procedural revisions have greatly increased their post-1995 estimated values. The revisions left the overall 1995-2000 direct LP growth rate relatively unchanged. However, the industry LP rates were raised, especially within the services sector, as were the sizes of the reallocation effects. Because BEA's methodological changes caused more integration of the industry accounts and the input-output accounts, they may have improved the measurement of inter-industry flows in the industry accounts. The new estimates of reallocation effects may be revealing an economic phenomenon that was probably always important in industry productivities, but was hidden by the less effective methodology of the past.[16]

We think that further analysis of reallocation effects is needed. For example, recent U.S. productivity performance relative to the European Union (EU) has provided much fodder for policy discussions. The frequently-encountered idea that less regulation in the United States (relative to the EU) is the source of its better productivity performance rests on the interpretation that *aggregate and sector* LP growth is the result of production function shifts and capital-labour substitution. Some of it, instead, reflects the U.S. economy's recent more favorable shift of resources into subsectors that have higher productivity growth. Until we know more about the nature of those resource shifts, one cannot claim that deregulation (or other favored nostrums) will augment them favorably, no matter how attractive are the intellectual cases to be made for less regulation.[17]

Services Industry Productivity Measures

As we have used it, the BEA industry dataset contains 23 goods-producing industries and 34 services industries, at roughly the 3-digit level of the NAICS classification. Productivity advance, post-2000, remains broadly based both in goods and in services industries.

As Table 5 shows, 70 per cent (16 of 23) of goods industries and 65 per cent of services industries (22 of 34) experienced more rapid LP growth after 1995, considering the whole 1995-2005 period together.[18] For MFP, the picture is similar: 57 per cent of the goods industries and 65 per cent of the services industries showed accelerating productivity, again considering the whole period 1995-2005 compared with pre-1995. Thus, goods and services industries advanced in MFP in roughly similar proportions for the period after 1995. Productivity advance in U.S. industries — MFP as well as LP — was not narrowly located in electronics, contrary to assertions that have often been repeated.

16 Triplett and Bosworth (2004, Table 2-5) computed reallocation terms and discussed them, but they appeared smaller in the data that were available at the time.

17 Lest we be misinterpreted, we share the usual economists' presumption against excessive regulation. What we are saying is that the empirical case linking deregulation to accelerating U.S. sector and aggregate LP and MFP measures is weak, and is weaker still when the substantial roles of reallocation effects are considered.

18 The old BEA dataset used for our book contained 29 services industries. We reported in our book that productivity growth increased in 18 of the 29, comparing 1995-01 to the pre-1995 period (Triplett and Bosworth, 2004, page 17). Allowing for the changed number of industries (choice of end point—2000 or 2001—made no difference), this is essentially the result noted above.

Table 5
Industry Productivity Accelerations, 1987-2005

	1995-00/ pre-1995	2000-05/ pre-1995	1995-2005/ pre-1995
Number of goods industries	23	23	23
Per cent accelerating LP growth	57	74	70
Per cent accelerating MFP growth	43	70	57
Number of services industries	34	34	34
Per cent accelerating LP growth	62	68	65
Per cent accelerating MFP growth	53	65	65

Source: Computed by the authors from the new NAICS-based industry data set, December 2006 release.

Non-accelerating industries

There are 10 contrary services industries — those for which LP and MFP growth over the combined 1995-2005 interval failed to accelerate, compared with pre-1995 rates.[19] Four are in transportation. They deserve further study. Only trucking has any kind of productivity literature — our trucking industry measures derived from BEA and BLS data seem inconsistent with Hubbard's (2003) results.

Of the other six industries, a number present measurement problems. The Federal Reserve and credit intermediation industry (negative MFP or LP growth rates in at least one period) is not only a somewhat miscellaneous grouping, it is likely distorted with the error created by the inappropriate national accounts measure of the output in financial institutions.[20] Education is the sick child of services productivity, with measured LP and MFP that is negative and growing more so; the output of the industry, and therefore its productivity, may be mis-measured, but education may also be the archetypal "Baumol's disease" industry (Baumol 1967). Performing arts and amusements are now also negative productivity growth industries; no research exists on productivity in these growing industries. The negative rates in "other services except government" are hard to assess.

Better output measurement would likely turn some of these seeming laggards into better productivity performers. On the other hand, we also suspect mismeasurement in some industries that show high measured LP growth rates. Airline transport — whose measured LP growth became strongly positive, post-2000 — may be overstated.

MFP and lagged investment in IT

Basu and Fernald (2006) explore whether MFP growth is a function of lagged investment in IT. They reason that increasing (measured) MFP may result from omission from the capital input measures of unobserved intangible capital and "coinvestments" that are associated with investment in IT (many other authors have advanced the same hypothesis). They take the share of IT in industry value added as a proxy for the unobserved investments. Basu and Fernald report evidence that they characterize as "somewhat consistent" with the lagged hypothesis. Basu *et al.* (2004), in a paper that uses a version of the data for our book, reported similar findings for the 1995-2000 period.

We looked at this question briefly in our book (Triplett and Bosworth, 2004: 29-31). We found no relation between the IT intensity of an industry (we used the share of IT in capital services) and its subsequent MFP growth. We examine the question again with our new data.

We computed several regressions of industry MFP change on its lagged IT. In the regression whose results were most favorable to the lagged IT hypothesis, we used the ratio of IT capital income to value added as the measure of industry IT intensity (this measure is close to the Basu and Fernald measure).[21] Thus, our regression includes as right-hand variables the current five-year period's IT intensity (expected to have a neg-

19 The growth accounting results for all 57 industries are posted at www.csls.ca/ipm/4.asp.

20 See chapters 5 and 7 of our book (Triplett and Bosworth, 2004) and Basu, Inklaar and Wang (2006).

Table 6

OLS Regression of IT Intensity Level on MFP Growth[1]

		IT Intensity	Lagged IT Intensity	Double Lagged IT Intensity	Adjusted R-squared	Observations
All Industries	1995-00	-12.17	13.82		-0.03	57
		(0.31)	(0.37)			
	2000-05	-128.00*	146.94*		0.16	57
		(3.48)	(3.59)			
	2000-05	-128.00*	124.69*	23.46	0.17	57
		(3.46)	(2.71)	(1.05)		
Services	1995-00	-42.12	38.43		-0.02	34
		(1.17)	(1.12)			
	2000-05	-44.60	55.61		-0.02	34
		(0.98)	(1.09)			
	2000-05	-38.87	21.26	30.39	0.01	34
		(0.86)	(0.38)	(1.38)		
Goods	1995-00	98.02	-13.86		-0.01	23
		(0.62)	(0.07)			
	2000-05	-246.00*	257.59*		0.41	23
		(3.85)	(4.11)			
	2000-05	-233.00*	189.17	84.33	0.40	23
		(3.48)	(1.68)	(0.74)		
Goods ex. Computers	1995-00	87.67	-104.00		0.01	22
		(1.52) -	(1.34)			
	2000-05	89.53	100.58		-0.05	22
		(0.9)	(1.02)			
	2000-05	-50.60	-23.27	129.51	-0.02	22
		(0.49)	(0.16)	(1.21)		

Source: Authors' calculations as explained in text.

1 IT Intensity is the ratio of IT capital income to Value-Added.

Notes: The items in parentheses are t-statistics. The regressions also included a constant term (not shown).

* indicates significance at the 1% level of a two-tailed t-test.

ative sign, on the grounds that resources are being diverted to coinvestments without a current payoff), the IT intensity of the previous period (e.g., for 1995-2000 the lagged IT for 1987-1995, expected to have a positive sign, as coinvestments begin their payout), and IT intensity lagged two periods (available for the post-2000 period only). Table 6 shows the results.

Scanning down the columns, most of the signs are consistent with the hypothesis —negative on current IT, positive on lagged IT, but coefficients are mostly statistically insignificant. At the all-industries level, signs are correct and statistically significant only for post-2000, not for 1995-2000. Possibly Basu *et al.*'s significant findings for 1995-2000 are casualties of data revisions.

21 In another, we used the IT capital contribution to industry LP as the measure of IT intensity. Entered into a lagged regression it yielded very low t-values and essentially zero adjusted R^2, so we did not consider this formulation further. There is no natural measure of IT intensity (Triplett and Bosworth, 2006 discuss nine alternatives), and rankings of industries by IT intensities are not invariant to the measure chosen.

We then disaggregated our investigation, running separate regressions for goods industries and services industries. For services industries, signs were correct in both periods, but t-values were weak. For goods, as in the all-industries regression, signs were correct for post-2000 (but not for 1995-2000), and t-values for post-2000 were highly significant. Examination of the data for individual industries suggested running another goods industry regression with the computer and electronics industry deleted: The results resemble the results for services — signs for the post-2000 period (only) remain correct but t-values drop to insignificance. When the second lagged variable is included in this regression, it has the expected sign, but the first lagged variable becomes negative. In any case, however, none of the coefficients is significant.

We conclude from this that the computer and electronics industry is not only an outlier, but that it has a tremendous impact on the goods industries and all industries regressions. Computer and electronics production has the highest MFP growth in our dataset (11.00 and 6.17 per cent per year for, respectively, 1995-2000 and 2000-2005), and it is not IT nor capital intensive by our value added measure. Outside of this industry, the lagged IT hypothesis has no statistical support in the industry data set. If the hypothesis describes something about IT investment, then empirically it *must* reveal itself in services industries because 80 per cent of U.S. IT investment is in the services sector.

Undoubtedly, investment in computers requires coinvestment. Lags are likely before the full potential of these investments are realized. However, we think these are properties of all investment and not particular or unique properties of computers.

Many of the management changes that have launched the revival of U.S. productivity growth are IT-enabled changes — computer equipment and software were required to put into effect the innovations that managers sought to make.[22] However, for the management resources used to make thousands of different innovations across our 57 diverse industries to be strongly correlated with the amount of IT used in each of these innovations would be an unlikely coincidence. The contribution of management inputs, coinvestment and intangible investment to recent productivity advance needs exploration. Indeed, our findings of major acceleration in MFP in services industries serves to confirm the importance of looking for other input variables, since growth in MFP can be a sign that something is omitted from the analysis. We believe, though, that finding the sources of the surge in MFP growth that has marked the U.S. economy over the last decade will require a great effort to enumerate and measure those omitted variables. Tempting as it may be to short-circuit the measurement process with ever more elaborate econometrics on the measures we already have, it is unlikely (as Zvi Griliches was fond of pointing out) to work.

Computers and semiconductors

In the previous literature on the post-1995 productivity advance, a great amount of ink was spilled recording indirect estimates of the rate of productivity advance in the electronics sector. The estimates had to be indirect because in the old U.S. SIC classification system, computers were buried, as we have remarked before, with drill bits in industrial machinery, while semiconductors were in the same industry as Christmas tree lights. The new NAICS classification system contains a computer and electronics manufacturing subsector, so in our data we can form a direct estimate of LP and MFP growth for this important industry. Our estimates are in Table 7.

22 Eric Brynjolfsson, the discussant for this article at the 2007 AEA session in Chicago, remarked that one could think of IT investment being a function of management innovation equally well as coinvestment being a function of IT and computers. The investments and the associated changes in organization and methods of doing business are all wrapped up in one decision process.

MFP growth in computers and electronics has been dazzlingly rapid. Even before 1995, it exceeded 5 per cent per year, and reached 11 per cent during 1995-2000 (MFP calculated consistently with the gross output growth accounting equation (1)). This latter estimate is somewhat below that of Jorgenson, Ho and Strioh's (2002), who estimated 16.8 per cent per year for computers and 18.0 per cent for electronics for the same period. Oliner and Sichel (2002) estimated 14.0 per cent for computer MFP growth and 45.2 per cent for semiconductors for 1995-2000; both are components of the present BEA industry, but other elements are included as well. Using our present data, at its height this one industry's MFP contributed 0.70 percentage points to non-farm LP growth, which is not far from the contribution that Oliner and Sichel obtained from quite indirect methods. [23]

One service industry had comparable LP and MFP growth rates — securities and commodities exchanges. Brokerage MFP, at nearly 11 per cent, had the second fastest MFP growth in 1995-2000, and again in 2000-2005. Its contribution to non-farm LP was lower because it is a smaller industry, about half the size of computer and electronics manufacturing in terms of value added.

Table 7
MFP in Computers and Brokerage Firms, 1987-2005
(average annual per cent or percentage point change)

	1987-95	1995-00	2000-05
Computers			
Industry MFP growth	5.7	11.0	6.2
MFP contribution to non-farm LP	0.33	0.70	0.27
Brokerage Firms			
Industry MFP growth	4.9	10.8	4.9
MFP contribution to non-farm LP	0.09	0.35	0.17

Source: Authors calculations from the new NAICS-based industry data set, December 2006 release.

Conclusion

In an otherwise excellent recent review of the post-1995 productivity expansion, Anderson and Kliesen (2006: 181) state: "...economists have reached a consensus that...the underlying cause of that increase [in U.S. labour productivity in the 1990s] was technological innovations in semiconductor manufacturing... ." If this is indeed the consensus, we contend it is wrong.

Two forces, not one, drove the 1995-2000 productivity expansion: Investment (much of it in IT) and MFP, much of the latter in services industries. Anderson and Kliesen focus, as did the researchers who preceded our work, on the contribution of IT investment (capital deepening) and MFP in IT production, without considering at all the contribution of MFP acceleration in services industries.[24] The advance in productivity that began in 1995 is a widespread phenomenon that was caused by more far-reaching economic forces than merely the rate of technical advance in the production of semiconductors (though we do no minimize the importance of technical change in electronics production and of capital deepening in raising U.S. LP).

We examine in this article the post-2000 productivity expansion, using our industry productivity approach. We again find that productivity growth was driven by capital deepening, this

23 The entries for contributions in Table 7 differ from the corresponding ones in Table 2 because Table 2 presents direct non-farm business sector LP, and the direct LP growth rate is based on value added. In interpreting these numbers, the reader should bear in mind that because productivity decelerated in some industries, the industries in which productivity accelerated contributed more than 100 per cent of the total acceleration.

24 On services productivity, Anderson and Kliesen (2006:184) state: "Increased use of ICT capital was the primary cause behind the productivity acceleration." They then quote from our book a passage in which we said that IT capital deepening in the U.S. was a services industry story. But we did not say that services productivity was an IT story — a very different thing. IT made a contribution to services labour productivity, but more remarkable was the acceleration of MFP growth in the services industries (see Triplett and Bosworth, 2004, Table A-2). In the data then available, services LP grew 2.56 per cent per year, of which IT contributed 1.01 points and MFP 1.48 points.

time not primarily in IT, and by productivity advance in services industries, especially MFP in services. The notion that the U.S. productivity revival rests fragilely on possibly transitory technological changes in one technologically dynamic industry is not consistent with the U.S. industry productivity data and has led to mistaken analysis and too pessimistic forecasts.

However, the industry productivity aggregations have brought to the fore a new factor: Resource reallocations have fluctuated in recent years, and estimates of their size have increased with BEA revisions to its industry accounts. Since 2000, reallocations have boosted services sector productivity change relative to services industry productivity change. It is still true that the foremost transition in the U.S. economy after 1995 was the revival of U.S. services industries. But whether early 21st century productivity growth has held up (to 1995-2000) or whether it has fallen short, depends on how one asks the question: Measured at the sector level, productivity growth has held up; at the industry level, LP growth has fallen.

MFP is a residual, after accounting for all contributing inputs. If variables are not measured appropriately, or if crucial inputs are omitted, then MFP growth may indicate where mismeasurement is worsening. The mismeasurement hypothesis (initially explored by Jorgenson and Griliches, 1967) provides the bridge to our complementary paper (Triplett and Bosworth, 2007), where we assess the adequacy of services sector data.

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