

# The Industry Anatomy of the Transatlantic Productivity Growth Slowdown: Europe Chasing the American Frontier

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## ABSTRACT

By merging KLEMS data covering 16 industry groups within the total economy and 11 manufacturing sub-industries, we compare and contrast productivity growth from 1950 to 2015 in the United States with an aggregate of the ten largest European nations (EU-10) from 1972 to 2015. We interpret the EU-10 performance as catching up to the United States in stages. Strikingly, the total economy “early-to-late” productivity growth slowdown from 1972-1995 to 2005-2015 in the EU-10 (-1.68 percentage points) was almost identical to the U.S. slowdown from 1950-1972 to 2005-2015 (-1.67 percentage points). There is a very high EU-U.S. correlation in the magnitude of the early-to-late slowdown in each industry, suggesting that the productivity growth slowdown from the early postwar years to the most recent decade was due to a retardation in technical change that affected the same industries by roughly the same magnitudes on both sides of the Atlantic.

Slowing labour productivity growth for any given income share of labour directly limits the growth rate of real wages and of a nation’s standard of living. Each percentage point by which labour productivity growth declines from its previous value translates into a one percentage-point re-

duction in the growth rate of potential output, which in turn reduces the capacity of a nation to finance national security, education, health care, and old-age pensions. Taking real GDP per hour worked as the broadest measure of labour productivity, its growth rate in the United States has

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declined from 2.7 per cent per year during 1950-1972, to 1.9 per cent during 1972-2005, to 1.1 per cent during 2005-2017. In this article we will examine the behavior of 10 of the 15 Western European members of the European Union prior to its 2004 enlargement (the “EU-10”). For this group of ten Western European countries, including all the large ones, the same growth measure declined even more sharply from 4.9 per cent per year during 1950-1972, to 2.3 per cent during 1972-2005, to a mere 0.7 per cent during 2005-2017.<sup>2</sup>

This article provides a comprehensive examination and comparison of labour productivity growth by industry in the United States back to 1950 and in the EU back to 1972, using KLEMS data that imposes uniform definitions and concepts on productivity and related data in each nation that is included. Our data allow a standard growth accounting decomposition of productivity into its three contributions of capital deepening, labour composition, and multifactor productivity (MFP). Beyond that, we can identify which industries grew rapidly and slowly in each subperiod and can create measures of the relative contribution to overall productivity growth of individual industries. Further, the data allow a growth accounting decomposition at

the industry level, so that we can identify industries in which a slowdown in capital deepening or in MFP was particularly important.

The use of KLEMS data offers two advantages beyond consistent concepts and definitions. First, in contrast to the recent studies at the industry level limited to the United States, our data allow a detailed comparison with the EU. Second, in contrast to recent U.S. research (e.g., Baily and Montalbano, 2016, and Murray, 2018) based on the industry data base of the Bureau of Labor Statistics, which is currently available only back to 1987, we have been able to merge different vintages of KLEMS data into a single U.S. industry database that extends from 1950 to 2015.<sup>3</sup> For the EU we have merged two data sets that allow our analysis to extend from 1972 to 2015 and to cover ten<sup>4</sup> of the 15 nations of the EU-15, including all the largest nations, hereafter the EU-10.

There are two important differences in the timing and pace of the productivity growth slowdown in the United States and EU-10.<sup>5</sup> The first, already identified above, is that the post-1972 slowdown in the EU was much sharper than in the United States. The second is that the United States enjoyed a temporary productivity

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2 The labour productivity growth rates for the United States and EU-10 in this paragraph come from the Conference Board Total Economy Database.

3 As indicated below, the U.S. data extend back to 1947 but we exclude 1947-1950 due to implausible behavior in the KLEMS data for public sector administration.

4 The ten included nations are Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, and the U.K. The nations in the EU-15 that are omitted are all small — Finland, Greece, Ireland, Luxembourg, and Portugal. Their combined GDP in 2017 was only 7 per cent of the GDP of the EU-15 (Source: Conference Board Total Economy Database).

5 For the remainder of the article the term “productivity growth” refers to labour productivity, while the abbreviation MFP refers to multi-factor productivity growth. Also, all growth rates cited in this article are annual growth rates calculated with logarithms.

growth revival between 1995 and 2005 that is missing in the EU experience. Dividing up the postwar into periods delineated by 1972, 1995, and 2005, the EU experienced a continuous deceleration from 1950-1972 to 1972-1995 to 1995-2005 to 2005-2015, whereas the United States experienced a slowdown from 1950-1972 to 1972-1995, then a marked but temporary growth revival in the 1995-2005 interval, followed by another slowdown after 2005.

Despite these differences, this article provides a new interpretation that points to similarities between the United States and EU-10 experience both in the aggregate and in the identity of those industries that made the largest contributions to changes in productivity growth over the intervals divided at 1972, 1995, and 2005. In our interpretation the EU was playing catchup to the United States over the entire period from 1950 to 1995, i.e., it was performing consistently with the convergence hypothesis. Starting in 1950 at a productivity level only 50 per cent of the United States, the EU caught up to 81 per cent by 1972, growing much more rapidly as it rebuilt after the war and implemented the large backlog of inventions and innovations that had propelled U.S. growth in the first half of the 20<sup>th</sup> century. After 1972 it continued to converge but at a slower pace, and we show that EU productivity growth in 1972-1995 was a mirror image of U.S. growth in the prior 1950-1972 interval, not only in the sense that the growth rates of productivity were identical, but also that there is a

high correlation across industries between the EU 1972-1995 and the United States 1950-1972 in the industry-by-industry productivity growth rates.

By linking the U.S. experience in 1950-1972 to the EU-10 growth pattern of 1972-1995, we are able to point to another striking similarity. The productivity growth slowdown from these early periods to the most recent 2005-2015 interval was almost identical: -1.68 percentage points for the EU-10 and -1.67 points for the United States. Further the industry-by-industry composition of the slowdown was very similar, with a high correlation across industries in the extent of the early-to-late slowdown.<sup>6</sup> These similarities shed new light on the frequent claim that the EU suffers from “Eurosclerosis.” Viewed in this new light, the productivity growth experience of the EU-10 reflects an extended period of catchup with an endpoint in the 2005-2015 interval that mimicks the U.S. experience over the same interval.

Throughout the article we distinguish between industries producing commodities and those producing services. We show that the 1972-1995 U.S. productivity growth slowdown occurred entirely within the commodities sector, with no slowdown at all for services, while most of the 1995-2005 U.S. revival likewise occurred in commodities. The post-2005 U.S. slowdown occurred equally in commodities and services industries. For the EU-10 the contrast is not as sharp, but the early-to-late EU slowdown was twice as great in com-

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<sup>6</sup> The “early-to-late” slowdown refers to the change in U.S. productivity growth from 1950-1972 to 2005-2015 and to the change in EU-10 productivity growth from 1972-1995 to 2005-2015.

modities as in services. Part of our interpretation is that the technological innovations of the first half of the century and the early postwar years disproportionately benefitted commodities, and so commodities had “further to fall” when the exploitation of those technological advances ran its course. A more surprising conclusion is the large role of commodities in the 1995-2005 U.S. productivity revival, given the emphasis in the literature on the role of the digital revolution in changing business practices in the services sector.

We also perform a calculation of sources of growth over each time interval, decomposing labour productivity growth. We show that MFP changes dominated the post-1972 U.S. slowdown and 1995-2005 U.S. revival, whereas declines in the respective contributions of MFP and capital deepening share roughly equal responsibility for the post-2005 U.S. slowdown as well as the early-to-late EU-10 slowdown. The role of the KLEMS measure of changes in labour composition is trivial in all the transitions across time intervals. The sources-of-growth analysis includes a ranked display by industry of the MFP contributions to the overall slowdown and points to a largely similar cast of characters in the industries that exhibit the largest overall slowdowns in their MFP contribution, again pointing to a technological explanation of the overall slowdown.

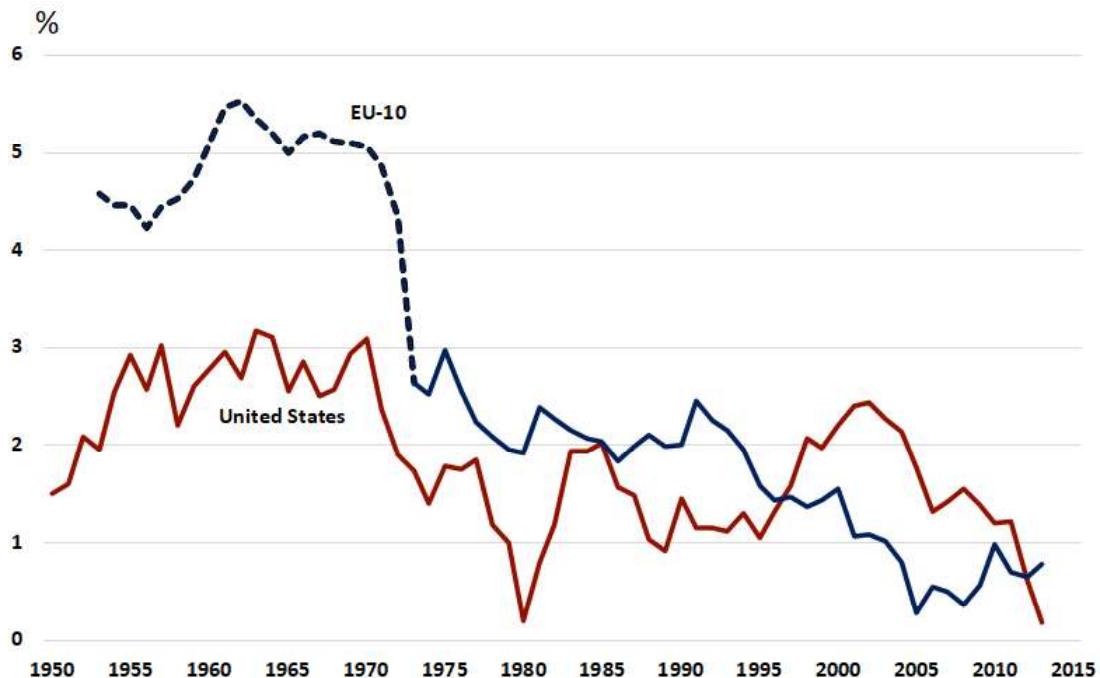
Despite these similarities between the United States and EU-10, the 1995-2005 U.S. revival contrasts sharply with the post-1995 EU slowdown. The ratio of the level of EU-10 productivity to that of the United States fell from 106 per cent in 1995 to 90 per cent in 2005. We show

that the ranking of industries in their 1995-2005 growth rates was similar in the United States and EU-10 but that for most industries European growth was only about half that in the United States. An extreme outlier was the electric machinery industry, where the production of information-communication technology (ICT) equipment is located in our KLEMS data. That industry achieved an annual growth rate of productivity for 1995-2005 of 17.6 per cent in the United States compared to 4.8 per cent in the EU-10.

One of the ironies of our overall conclusions is that the EU-10 was very successful in catching up to the United States pre-1950 performance in 1950-1972 and to the United States 1950-1972 performance during 1972-1995. But the EU-10 utterly failed to catch up to the U.S. revival of 1995-2005, either before or after 2005.

The paper begins in Part 2 with the basic facts about the evolution of labour productivity growth in the U.S. and EU-10. Parts 3 and 4 examine the industry anatomy of productivity growth in the U.S. over four time intervals, both for the 16 major sectors of the economy and for the 11 components of manufacturing. Parts 5 and 6 examine the same industry decomposition for the EU-10 and provide comparisons and correlations across industries and time periods with the U.S. Part 7 provides a sources-of-growth decomposition to examine the extent to which the slowdown in labour productivity growth was caused by declining TFP growth or a decline in capital-deepening. Part 8 examines alternative hypotheses to explain U.S. vs. EU-10 differences, and Part 9 concludes.

**Chart 1: United States vs. EU-10 Labour Productivity Growth 1950-2015, Centered Five Year Moving Averages, Total Economy**



Source: KLEMS data as described in Data Appendix, except for EU-10 1950-1972 for the Total Economy, which is GDP per hour from the Conference Board Total Economy Database, weighted together for the 10 EU nations using real GDP weights.

## The Economy-wide Growth Experience

Before examining data at the level of individual industries, we provide a depiction of labour productivity growth and its major contributing factors for the total economy and several of its main sectors. Chart 1 compares the rate of labour productivity growth for the total economy (not the “business” or “market” sector) in the United States and EU-10 from the KLEMS data. To smooth out sharp changes from year to year, the data are plotted as cen-

tered five-year moving averages of annual growth rates. Shown for the United States is the growth rate for 1947-2015, implying that the centered five-year moving averages extend from 1949 to 2013. For the EU-10 the same series is based on data from 1972 to 2015. To extend the EU-10 data backwards before 1972 for comparison with the United States, we use real GDP per hour from the Conference Board Total Economy Database.<sup>7</sup>

Turning first to the U.S. growth rate in Chart 1, we note that the five-year moving averages do not remove all of the cycli-

<sup>7</sup> In Chart 1, Table 1, and the subsequent analysis, growth rates for the EU-10 aggregate are calculated by taking the growth rates for an individual country and weighting that growth rate by the share of its real GDP in total EU-10 real GDP, where the GDP data come from the Conference Board Total Economy Database.

cal movements. There are sharp troughs in 1980 and 2013. Observing longer-term trends, we note that U.S. productivity growth was relatively rapid in the 1950s and 1960s, slowed appreciably from the early 1970s through the mid-1990s, exhibited a revival between 1995 and 2005, then during 2006-11 returned to the rates of the 1970s and 1980s before plummeting toward zero in the last two years. This alternation between fast and slow periods of growth characterizes the U.S. postwar experience, and as we shall see the most important contributors to this zig-zag pattern are industries that produce commodities, not industries that produce services.

The evolution of the centered five-year moving averages for the EU-10 is smoother than for the United States, with no sharp troughs. This may reflect the fact that the EU-10 growth rates are weighted averages across 10 different nations, each of which may have experienced different cyclical peaks and troughs. Unlike the United States with its late 1990s revival, the EU-10 experience appears to be a continuous slowdown in stages. Productivity growth was greater than 5 per cent per annum between 1960 and 1971, then slowed sharply to the range of 2 to 3 per cent during 1973-96, then slowed further to the range of one to two per cent during 1997-2007, and remained below 1 per cent per year after 2007.

The trends of average annual productivity growth rates over sub-intervals divided at 1972, 1995, and 2005 are shown in Table

1 for the United States and EU-10, and for the total, market, and non-market sectors<sup>8</sup>. The market economy is subdivided between the commodity-producing (CP) industries and the service-producing (SP) industries. For the U.S. total economy, the growth rates alternate between high and low. The difference between the high and low periods is greater for the market economy than for the total, reflecting the fact that the non-market economy exhibits the opposite pattern by growing faster in 1972-1995 and 2005-2015 than in 1950-1972 or 1995-2005. The 1995-2005 revival in the market economy brought its growth rate up to 2.89 per cent per year, close to the 3.05 per cent per year registered for 1950-1972, while the final interval of 2005-2015 experienced a growth rate of 0.86 per cent, lower than the previous slow period of 1972-1995 when market productivity growth was 1.66 per cent.

The decomposition of the market economy into the CP and SP sub-sectors reveals a surprising fact that has escaped comment in most of the recent literature on the U.S. productivity revival and slowdown. Virtually all of the post-1972 slowdown and most of the 1995-2005 revival occurred within the CP industries, with no difference in the productivity growth rate of the SP industries when 1950-1972 is compared to 1972-1995 and only a relatively small SP revival in 1995-2005. However, the CP and SP industries experienced a similar post-2005 slowdown; when compared to 1995-2005 the CP slowdown was 2.33 percentage

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<sup>8</sup> The distinction between the market and non-market sectors follows the KLEMS convention and is outlined in Timmer *et al.* (2007)

**Table 1: Annual Average Growth Rates of Labour Productivity by Sector, Selected Intervals, 1950-2015**

	1950-72	1972-95	1995-2005	2005-15	Slowdown in 2005-15 from 1950-72	Slowdown in 2005-15 from 1972-95
<b>U.S.</b>						
Total	2.54	1.25	2.17	0.87	<b>-1.67</b>	
Market	3.05	1.66	2.89	0.86	<b>-2.19</b>	
Commodities	3.39	1.45	3.60	1.27	<b>-2.13</b>	
Services	2.19	2.20	2.84	0.90	<b>-1.29</b>	
Non-market	0.07	0.83	0.63	0.88	<b>0.81</b>	
<b>EU-10</b>						
Total	4.86	2.31	1.26	0.63		<b>-1.68</b>
Market	N/A	2.47	1.61	0.72		<b>-1.75</b>
Commodities	N/A	3.11	2.26	0.95		<b>-2.15</b>
Services	N/A	1.69	1.23	0.64		<b>-1.05</b>
Non-market	N/A	0.56	0.26	0.19		<b>-0.37</b>

Note: All cells are computed from the merged KLEMS data base as described in the Data Appendix except for the EU-10 in 1950-72, which comes from the Conference Board Total Economy Database.

points in comparison to the SP slowdown of 1.94 points.<sup>9</sup>

The story is simpler for the EU-10, where total economy productivity growth decreased in each period, most sharply between 1950-1972 and 1972-1995. Growth in the market sector was modestly faster than in the total economy in each interval, while growth in the non-market sector was slower and exhibited a steady slowdown in contrast to the alternation visible in the non-market data for the United States. For the total economy trend growth in the EU-10 started out at double the rate of the United States in the initial 1950-1972 interval and gradually decreased until in 2005-2015 it was virtually identical. EU-10 growth in the non-market sector was substantially slower than in the United States in the last two intervals following 1995. The distinction between the CP and SP in-

dustries is also more straightforward for the EU-10 than for the United States. CP productivity growth started out in 1972-1995 roughly double that of the SP industries and then slowed down more rapidly, so that by 2005-2015 CP and SP growth were little different. This reinforces our emphasis on the importance of the CP industries as contributors to the overall slowdown between the early and late time intervals in both the United States and the EU-10.

The fact that the EU-10 had more rapid productivity growth than the United States prior to 1995 but slower growth after 1995 implies that the *level* of EU-10 labour productivity caught up to that of the United States prior to 1995 and then fell back after 1995. In the pre-1995 interval the EU-10 more than caught up to the United States, with the ratio of its productivity level rising from 50 per cent in 1950 to 81 per cent

9 The accentuated slowdown of the market sector relative to its sub-industries in commodities and services production between 1950-1972 and 2005-2015 is due to a compositional shift towards the services sector.

10 The ratio of EU-10 to U.S. labour productivity is based on a comparison of GDP per hour, with EU-10 GDP in purchasing-power-parity dollars aggregated and divided by hours. Source: Conference Board Total Economy Database.

in 1972 to 106 per cent in 1995.<sup>10</sup> Thus, despite suggestions in the literature that the European economy suffers from “Eurosclerosis,” structural flaws that prevent it from achieving the U.S. level of productivity, Europe actually exceeded the U.S. level from 1989 to 2000 before retreating as a result of its failure to duplicate the U.S. 1995-2005 growth revival. The ratio of the EU-10 to the U.S. productivity level declined from 106 per cent in 1995 to 90 per cent in 2005 and slightly further to 86 per cent in 2015.

An interesting feature of Table 1 is the close similarity of the U.S. growth rates in 1950-1972 with the EU-10 growth rates in 1972-1995, and the close similarity of the U.S. growth rates in 1972-1995 to the EU-10 growth rates in 1995-2005. In this sense the entire period from 1972 to 2005 can be characterized as “the EU-10 lagged 20 years behind the productivity performance of the United States.”

The rapid EU growth of 1950-1972 can also be interpreted as “catch-up”<sup>11</sup> growth after the economic dislocations of the two world wars and the interwar period, when the United States leaped ahead of the EU in its level of labour productivity. As noted, in 1950 the level of EU-10 labour productivity was only 50 per cent of the U.S. level, implying substantial room for catch-up. By 1972 Europe had time to adopt most of the inventions of the late nineteenth and early twentieth century that had become common in the United States before World War II, and so after 1972 EU-10 productivity growth slowed

down to a rate very similar to the U.S. rate in the early postwar years, 1950-1972. When we interpret 1950-1972 for the United States as being comparable to 1972-1995 for the EU-10, a remarkable fact emerges from Table 1, as shown in the two right-hand columns. For the total economy *the slowdown in labour productivity growth from these comparable periods to 2005-2015 was exactly the same, -1.67 points for the United States and -1.68 points for Europe.*

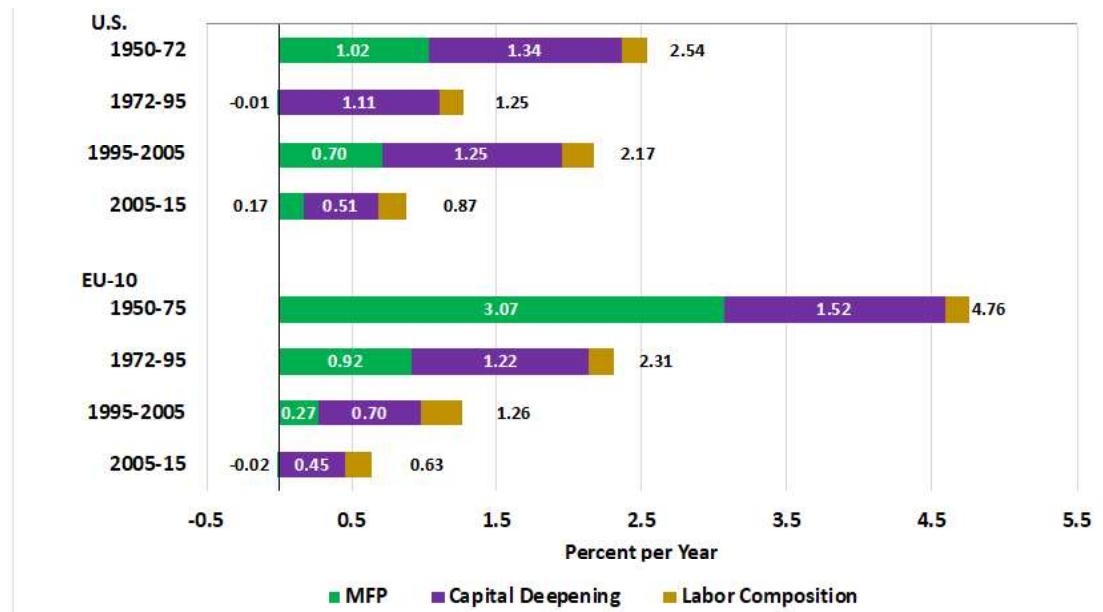
Within the market economy this measure of slowdown was also quite similar, and again the slowdown for the CP industries in Europe (-2.15 points) was exactly the same as in the United States (-2.13 points). The slowdown in the SP industries in the United States was slightly greater in the United States than in Europe (-1.29 vs. -1.05 points). The measure of slowdown was quite different in the non-market sector, reflecting the unusually slow growth for the non-market sector in the United States in the early postwar years.

The standard sources-of-growth decomposition divides growth in labour productivity among the contributions of multi-factor productivity (MFP), capital deepening, and changes in labour composition. Chart 2 provides for the same time intervals as Table 1 a graphical depiction of these three respective contributions to total economy labour productivity growth as green, purple, and gold slices in the horizontal bars, the total width of which represents labour productivity growth. Here we notice interesting differences between

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<sup>11</sup> Timmer *et al.* (2011) provide a similar diagnosis, arguing that from 1950 to 1973, European productivity was playing “catch up” with the United States — specifically through “technology imitation” and “new institutions.” They also concur that from 1973 to 1995 growth slowed as the EU “caught up.”

**Chart 2: Decomposition of Labour Productivity Growth Between MFP, Capital Deepening, and Labour Composition, Selected Periods, 1950-2015**



Source: All data except EU-10 for 1950-1975 are taken from the KLEMS series described in the Data Appendix. The EU-10 numbers from 1950-1975 are taken from Bergeaud, Cette, and Remy (2017: Table 1), which provides the data separately from the UK and Eurozone. These are weighted together by average 1950-1975 GDP of the listed nations from the Conference Board Total Economy Database. Unlike the other intervals for the EU-10, the series shown for 1950-1975 include Finland and Portugal, while excluding Austria, Denmark, and Sweden.

the United States and EU-10. For the United States the contribution of capital deepening was virtually the same in the first three periods — 1.34, 1.11, and 1.25 percentage points respectively, indicating that virtually all of the 1972-1995 productivity growth slowdown and 1995-2005 revival was due to variations in average MFP growth.

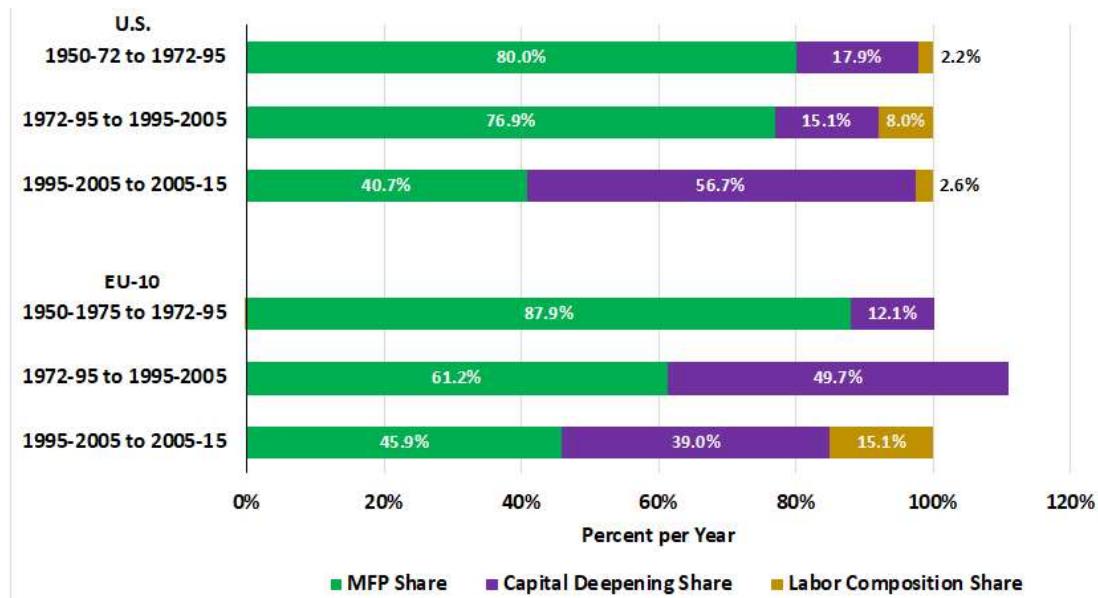
In contrast a reduction in the contribution of capital deepening accounted for more of the post-2005 productivity growth slowdown than the slowdown in the MFP contribution.<sup>12</sup> Based on a separate calculation that is not included in Chart 2, during 2005-2010, U.S. capital deepening

continued at a 1.11 per cent growth rate, similar to that observed before 2005, while MFP growth fell from 0.71 per cent in 1995-2005 to a negligible 0.21 per cent in 2005-2010. Then in 2010-2015 MFP growth continued at the even slower rate of 0.14 per cent while capital deepening growth plummeted to a negative -0.10 per cent rate. In this sense the slowdown was led by MFP, while capital deepening followed along with a lag.

For the EU-10 the relative roles of MFP and capital deepening were different than in the United States. In each of the transitions the slowdown in the growth rate of labour productivity is explained by a

<sup>12</sup> It is interesting to note that the first and last halves of the 2005-2015 interval were quite different for the United States (although not for the EU-10).

**Chart 3: Percent Decomposition of Labour Productivity Change Between MFP, Capital Deepening, and Labour Composition, Selected Periods, 1950-2015**



Source: All data except EU-10 for 1950-1975 is taken from the KLEMS series described in the Data Appendix. The EU-10 numbers from 1950-1975 are taken from Bergeaud, Cette, and Remy (2017: Table 1), which provides the data separately from the UK and Eurozone. These are weighted together by average 1950-1975 GDP of the listed nations from the Conference Board Total Economy Database. Unlike the other intervals for the EU-10, the series shown for 1950-1975 include Finland and Portugal, while excluding Austria, Denmark, and Sweden.

slowdown in both the contribution of MFP and of capital deepening.<sup>13</sup> In the first post-1972 transition the MFP contribution was substantially more important, but in the post-1995 and post-2005 transitions the MFP and capital deepening contributions were of roughly equal importance. The impact of the labour composition contribution was small and notably reversed sign toward a higher contribution in 1995-2005 than in the second and fourth intervals.

Chart 3 shows the relative importance of the contributions in explaining each of the transitions of Chart 2. Each horizontal bar sums to 100 per cent, and the same colors as in Chart 2 indicate the share of the

MFP, capital deepening, and labour composition contributions to the transitions between time intervals. For the United States the large green segments show the dominant role of MFP in causing the down and up of labour productivity growth in the 1972-1995 slowdown and 1995-2005 revival, while the large purple segment indicates the predominant role of capital deepening in the post-2005 slowdown. For the EU-10 the green MFP area indicates its major responsibility for the first 1972-1995 slowdown, while the roughly equal green and purple areas show joint responsibility in the 1995-2005 and post-2005 slowdowns. Note that the sum of the green and purple EU

<sup>13</sup> Charts 2 and 3 reach the same conclusion as Giombini *et al.* (2017), who concur that EU productivity slowed both because of smaller contributions of both MFP and capital deepening

bars for the post-1995 transition sums to more than 100 per cent, because the contribution of labour composition goes in the opposite direction (up) from the direction of the MFP and capital deepening contributions (down).

The green and purple shares in Chart 3 help to focus our attention on the underlying causes of the changes in labour productivity growth over these intervals. Viewed in this way, the U.S. 1972-1995 slowdown and 1995-2005 revival were largely a story of the shifting role of innovation, while the post-2005 slowdown combined the impact of innovation with a depressed contribution of investment. For the EU-10 innovation dominated in the first 1972-1995 slowdown, while innovation and investment shared responsibility for the further 1995-2005 and post-2005 growth slowdowns.

## **Industrial Sector Behavior for the United States**

In contrast to the EU-10, which experienced a steady slowdown in labour productivity growth from one time interval to the next, the United States alternated between a 1972-1995 slowdown, a 1995-2005 revival, and a second post-2005 slowdown. In this section we examine the industry breakdown of the three U.S. transitions and turn in the next section to the EU-10 slowdown and the contrast between its industry makeup and that of the United States.

Previous analyses of U.S. industry data have been based on the BLS data that are available for 60 different industries and have focused primarily on the 1995-2005 revival (Stiroh, 2002) or post-2005 slowdown (Murray, 2018) or both (Baily and

Montalbano, 2016). With so many industries behaving in different ways, it has been difficult for these studies to emerge with firm conclusions regarding the industry anatomy of these transitions. Here we begin with 27 industry groups from the KLEMS data and reduce that number to 16 by combining the 11 two-digit sub-industries of manufacturing into a single manufacturing sector (later we shall look at the manufacturing sub-industries separately). By aggregating into a smaller number of industries than the BLS data, the KLEMS data makes it more feasible to highlight the behavior of particular industries.

Table 2 presents labour productivity growth rates for the United States in our four time periods divided by 1972, 1995, and 2005. The industries are presented in the order of the KLEMS industrial classification, which places five commodity-producing industries first (agriculture, mining, manufacturing, utilities, and construction), followed by seven service-producing industries. Growth rates for five aggregates — total, market, non-market, commodities, and services — are shown in bold and are identical to the same growth rates presented above in Table 1.

In the initial 1950-1972 interval for the market sector, six industries registered above average growth rates. These were the first four listed commodity-producing (CP) industries, plus wholesale/retail and information/communication. All the industries with below-average growth were in the SP sector except for construction — notably two of the SP industries had productivity growth of near zero, and another two had negative productivity growth. Growth

**Table 2: Annual Labour Productivity Growth Rates by Industry Group, U.S., Selected Intervals, 1950-2015**

Industry	1950-72	1972-95	1995-2005	2005-15
<b>Total</b>	<b>2.54</b>	<b>1.25</b>	<b>2.17</b>	<b>0.87</b>
<b>Market</b>	<b>3.05</b>	<b>1.66</b>	<b>2.89</b>	<b>0.86</b>
<b>Commodities</b>	<b>3.39</b>	<b>1.45</b>	<b>3.60</b>	<b>1.27</b>
Agriculture	4.68	3.72	7.27	1.05
Mining	2.97	-0.27	-1.87	2.98
Manufacturing	3.41	2.43	5.53	1.90
Utilities	4.56	-1.24	1.20	-0.03
Construction	1.89	-1.44	-1.02	-0.92
<b>Services</b>	<b>2.19</b>	<b>2.20</b>	<b>2.84</b>	<b>0.90</b>
Wholesale & Retail	3.55	3.18	4.33	0.79
Transportation	2.37	1.43	1.48	-0.69
Hotels & Restaurants	-1.74	-0.67	1.81	-0.67
Information & Communications	4.33	5.46	4.04	3.05
Finance & Insurance	-0.19	3.65	3.77	0.80
Professions & Administrative	-	-0.60	1.20	1.07
Arts & Entertainment	-1.09	-0.14	-0.05	-0.10
<b>Nonmarket</b>	<b>0.07</b>	<b>0.83</b>	<b>0.63</b>	<b>0.88</b>
Real Estate	2.16	0.09	0.96	1.91
Public Sector	-0.93	1.47	0.55	0.33
Education	2.47	0.80	0.87	0.99
Health	0.06	-0.29	-0.25	0.34

Source: KLEMS Database.

in the nonmarket sector was negative, pulled down by the substantial negative growth rate of public sector administration. Since output in many parts of the public sector is measured by employment, this 1950-1972 negative rate of public sector productivity growth may be spurious in the underlying KLEMS data for this early time interval.

In the next interval — 1972-1995 — labour productivity growth declined by half in the total economy (from 2.54 to 1.25 per cent) and by almost half in the market sector (from 3.05 to 1.66 per cent).

Which industries accounted for the slowdown? As shown in Table 2 all of the slowdown was concentrated in the CP industries, since growth in the SP industries was exactly the same after 1972. In the market sector eight of the 12 industries registered slower growth after 1972, and seven of these were those listed at the top of the ta-

ble (from agriculture down through transportation services). The other was professional/administrative, which went from zero to negative growth. The remaining four industries experienced faster productivity growth, or in the case of hotels/restaurants and arts/entertainment a smaller negative growth rate. In the non-market sector there was a sharp turnaround in public administration from negative to positive growth, while the other three industries experienced slower growth. Overall, 11 of the 16 industries experienced slower growth.

Productivity growth revived from 1972-1995 to 1995-2005 in the total economy from 1.25 to 2.17 per cent and in the market sector from 1.66 to 2.89 per cent. Once again we see that the transition was dominated by the CP industries, which witnessed productivity growth more than double from 1.45 to 3.60 per cent, while the

revival for the SP industries was only from 2.20 to 2.84 per cent. Thus the CP industries grew faster than the SP industries in the first and third period but slower in the second period. This strong contribution of the CP industries to the 1972-1995 slowdown and 1995-2005 revival has received relatively little comment in the literature.

Six industries experienced an increase in productivity growth of more than 1 percentage point after 1995, and four of these achieved a growth rate faster than in the initial 1950-1972 period (agriculture, manufacturing, wholesale/retail, and professional/administrative). The sharpest changes in the 1995-2005 transition were for agriculture (3.55 percentage points), manufacturing (3.10), hotels/restaurants (2.48), and utilities (2.44). The remaining six industries experienced increases of less than one per cent or a decline in the case of mining and information/communication. Mining, construction, and arts/entertainment recorded negative productivity growth during 1995-2005. Productivity growth changed little on balance in the nonmarket sector, with little change in education and health, and with an increase in real estate offset by a decline in public administration.

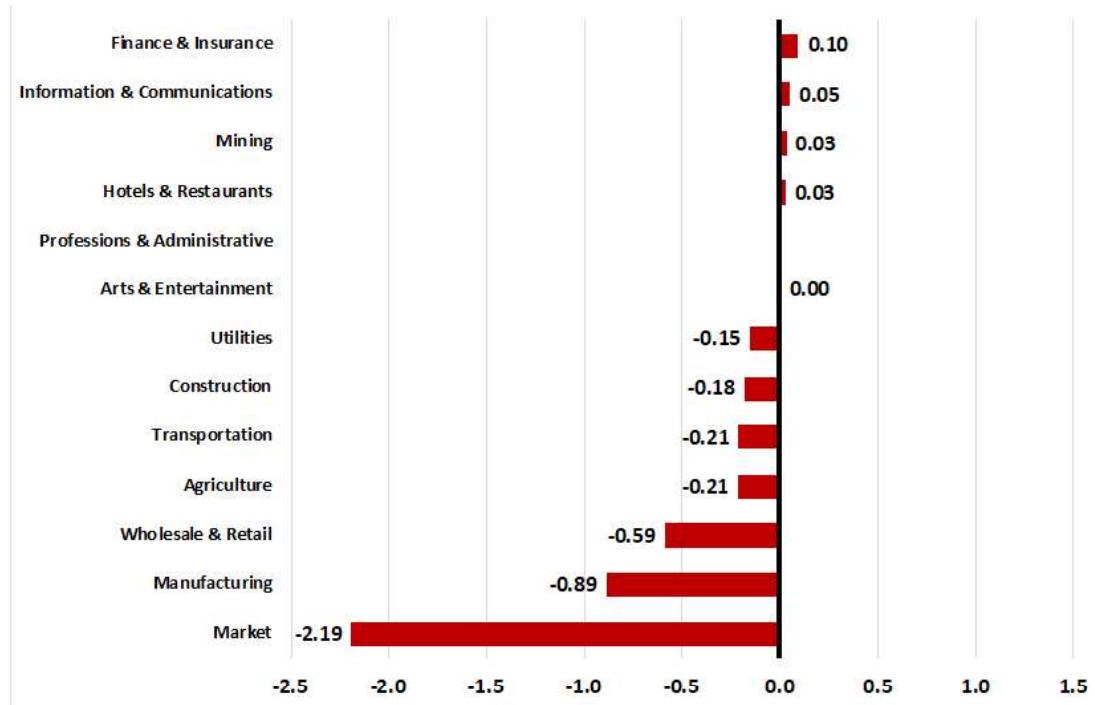
The second episode of slower productivity growth occurred after 2005, slowing from 2.17 per cent to 0.87 per cent in the total economy and from 2.89 to 0.86 per cent in the market sector. The decline of more than 2 percentage points in the market sector was greater than the previous slowdown from 1950-1972 to 1972-1995. Within the market sector the CP and SP industries recorded roughly similar slowdowns of -2.33 and -1.94 per cent respectively, as shown in

Table 2. Six industries experienced a decline of more than one percentage point *and* recorded lower productivity growth than in the previous slowdown period of 1972-1995. In descending order of the extent of the slowdown, these were agriculture (-6.22 percentage points), manufacturing (-3.63), wholesale/retail (-3.54), finance/insurance (-2.97), transportation services (-2.17), and information/communication (-0.99). Hotels/restaurants had a decline of -2.48 points to negative growth which exactly matched the negative growth of 1972-1995. Utilities experienced a slowdown of -1.23 points but grew faster than in 1972-1995. Mining was the notable outlier, experiencing a sharp growth revival of 4.85 per cent. The remaining industries in the market sector grew slowly and exhibited little change in the post-2005 transition. The nonmarket sector grew slightly faster after 2005, with a one point revival in real estate but little change otherwise.

Across the columns in Table 2, there is a relatively high correlation coefficient of 0.79 across market industries between the productivity growth rates of 1972-1995 and 1995-2005. This means that the industries that grew the fastest between 1972 and 1995 also grew the fastest between 1995 and 2005. The regression constant is 1.11 percentage points and the slope coefficient is a highly significant 0.92.

Perhaps most interesting is the strong negative correlation coefficient of -0.69 across the market industries between the 1995-2005 revival and the post-2005 slowdown. Those industries that experienced the largest revivals after 1995 also experienced the greatest slowdowns after 2005, particularly agriculture, manufac-

**Chart 4: Value-Added Weighted Contributions of Market Industries to U.S Labour Productivity Growth, 1950-1972 to 2005-2015 Transition**



Source: KLEMS Database.

turing, utilities, wholesale/retail, and hotels/restaurants.<sup>14</sup> The regression line has a constant term of -0.22 and a slope of -1.10. The high negative correlation is also supported by the turnaround in mining from a negative post-1995 change to a sharp positive post-2005 change. This correlation pattern is consistent with the hypothesis that the U.S. market economy experienced a temporary positive technological shock in 1995-2005 that dissipated after 2005, and this interpretation, consistent with much of the previous literature, is supported by the dominant role of MFP relative to capital deepening in explaining the 1995-2005 revival.

Which were the main industries that contributed to the overall decline from the first 1950-1972 interval to the final 2005-2015 interval? We can calculate the contributions of each industry to the total change in productivity growth over this transition. This is done by multiplying the change in productivity growth between time intervals by the average share in value-added of the particular industry over that time period. The results are displayed graphically in Chart 4 and focus on the market sector, omitting the four industries of the nonmarket sector to simplify the discussion.

Chart 4 displays as the bottom red bar the total change in the market sector of -

14 A graph illustrating this negative correlation appears in Baily and Montalbano (2016: Figure 9).

2.19 percentage points. Interestingly all of this contribution can be explained by the six industries listed at the bottom, while the six industries at the top made virtually no contribution to this overall change. Moving up from the bottom, in descending order of negative contributions, the industries making the largest contributions were manufacturing, wholesale/retail, agriculture, construction, transportation services, and utilities. Note that four of these produce commodities while the others produce services. The small role of services in this list suggests that the overall productivity growth slowdown over the postwar years has been heavily influenced by diminishing returns to innovations earlier in the 20<sup>th</sup> century that boosted productivity growth in the CP industries during 1950-1972 but faded out in importance after 1972.<sup>15</sup>

## **Industrial Sector Behavior Within U.S. Manufacturing**

So far we have considered only the behavior of the manufacturing sector as a whole. But the KLEMS data allow us to differentiate between 11 sub-industries within manufacturing, and Table 3 displays their growth rates of labour productivity in the same format as Table 2. Productivity growth was robust in the initial 1950-1972 interval, with seven of the eleven sub-industries displaying growth rates of 3.5 per

cent or above. The metals sub-industry was an outlier, with growth of only 1.14 per cent, and indeed experienced relatively slow growth in all four of the time intervals.

In the post-1972 transition productivity growth declined by 0.98 percentage points for total manufacturing and by more than 2 percentage points in 5 of the 11 sub-industries, with particularly sharp declines of more than 5 per cent in petroleum, chemicals, and machinery n.e.c. (“not elsewhere classified”). This response of petroleum and chemicals may reflect the influence of the oil price shocks of the 1970s, which raised the price of crude oil from \$3.56 in mid-1972 to \$39.50 in mid-1980.<sup>16</sup> The reason that the post-1972 decline for manufacturing as a whole was more modest than for most of the individual industries reflects the giant jump in the electric machinery industry from 4.24 to 13.49 per cent per year, reflecting the growing importance in this sector of the manufacture of ICT equipment.

As previously displayed in Table 2, the manufacturing sector enjoyed a sharp 1995-2005 revival in productivity growth from 2.43 to 5.53 per cent per year, or an increase of 3.10 percentage points. This increase as shown in Table 3 was consistent across sub-industries, as 6 of the 11 sub-industries experienced a productivity growth revival of 2 per cent or more, led by the enormous 8.58 percentage point revival for petroleum, and revivals of 3.5 percentage points or more for electrical machinery

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<sup>15</sup> Baily and Montalbano (2016) also highlight the role of agriculture, manufacturing, and retail/wholesale in the 1995-2005 productivity growth revival and post-2005 slowdown.

<sup>16</sup> Source: Spot crude oil price, West Texas Intermediate, from FRED.

**Table 3: Annual Labour Productivity Growth Rates by Industry Group, U.S. Manufacturing, Selected Intervals, 1950-2015**

Industry	1950-72	1972-95	1995-2005	2005-15
<b>Total Manufacturing</b>	<b>3.41</b>	<b>2.43</b>	<b>5.53</b>	<b>1.90</b>
Food	3.47	0.87	0.05	-0.43
Textiles & Apparel	4.55	4.72	3.63	1.20
Wood & Paper	2.10	0.27	2.15	1.46
Petroleum	8.24	2.41	10.99	-1.08
Chemicals	4.55	0.41	3.22	1.37
Rubber & Plastics	2.65	1.02	3.19	-0.78
Metals	1.14	1.05	2.25	0.50
Electrical Machinery	3.87	13.49	17.57	7.07
Machinery NEC	5.28	-0.60	3.02	0.64
Transportation Equipment	2.35	0.78	4.63	2.26
Other Manufacturing	5.16	2.91	3.32	1.79

Source: KLEMS Database.

(which reached a stunning growth rate of 17.6 per cent), machinery n.e.c., and transportation machinery. In four of these six industries with a revival of two per cent or more, productivity growth in 1995-2005 was faster than in the initial interval of 1950-1972, with an enormous margin for electrical machinery, while transportation equipment registered double the productivity growth in 1995-2005 as in 1950-1972. Only food and textiles/apparel experienced a productivity growth slowdown after 1995.

After 2005 overall manufacturing productivity growth slowed from 5.53 to 1.90 per cent, for a slowdown of 3.63 points. 6 of the eleven sub-industries experienced growth slowdowns of 2 per cent or more, led by the enormous declines of petroleum (-12 points) and electrical machinery (-10.5 per cent).<sup>17</sup> Seven industries display growth rates in 2005-2015 that are below their growth rates in the initial slowdown period of 1972-1995. Not a single manufac-

ting sub-industry recorded faster growth in 2005-2015 than in the prior period of 1995-2005.

To summarize the experience of the eleven sub-industries within manufacturing we can divide them into groups. Electrical machinery is in a category by itself, with rapid growth in all periods, double-digit growth in the two middle periods, and a sharp post-2005 slowdown to a growth rate of 7.07 per cent that was still relatively high. Next comes the majority of industries (seven of 11) that experienced a zig-zag from high growth in 1947-1972 to lower growth in 1972-1995, followed by a revival in 1995-2005 and a second slowdown after 2005. This group includes wood and paper, petroleum, chemicals, rubber and plastics, machinery n.e.c., transportation equipment, and other manufacturing. The three remaining industries display unique patterns — food slowed after 1972 with no 1995-2005 revival at all; textiles and

<sup>17</sup> Brill *et al.* (2018) in their analysis of BLS data conclude that most of the post-1995 and the post-2004 speedup/slowdown in manufacturing can be attributed to ICT producing industries. These authors also highlight the Petroleum industry as making a massive negative contribution, as is evident in Table 3.

apparel remained strong throughout until 2005 with no 1972-1995 slowdown; and metals registered slow growth throughout interrupted by a slight improvement in 1995-2005.

## **Industrial Sector Behavior for the EU-10 and EU-U.S. Comparisons**

The industrial breakdown of the EU-10 reveals a steady decline in productivity growth rather than the alternation of slowdown-revival-slowdown that we have observed for the United States. Table 4 displays EU-10 productivity growth for the same industries and same format as Table 2, but here we have three periods rather than four. Productivity growth slowed steadily across the intervals for the total economy, market economy, CP industries, SP industries, and the non-market sector.

In the initial 1972-1995 interval five of the 12 industrial sectors in the market sector exhibited growth of more than 2.5 per cent, and four of these five were CP industries, while the fifth was transportation services. Only one industry, hotels and restaurants, experienced negative productivity growth. As in the U.S. non-market productivity growth was slow, with negative growth in real estate.

When the 1995-2005 interval is compared with 1972-1995, all of the CP industries except for utilities experienced slower productivity growth. However, in the SP industries two of the

seven achieved faster productivity growth, namely information/communications and finance/insurance. These are two of the industries that we would expect to be most influenced by the ICT revolution of the 1990s. While information/communications experienced somewhat slower post-1995 growth in the United States, the transition was from a much higher growth rate (5.46 per cent to 4.04 per cent for the United States, 2.11 per cent to 3.84 per cent for the EU-10). Growth in the non-market sector slowed modestly in each industry except real estate, where productivity growth became slightly less negative.

Comparing Tables 2 and 4, we see that the EU-10 had faster productivity growth during 1972-1995 than the United States in eight of the 12 industries, including all five of the CP industries. The pattern was reversed for the 1995-2005 interval, with the United States having faster productivity growth than the EU-10 in seven of the 12 industries. However, while the EU had excelled in producing commodities in the earlier interval, the United States in 1995-2005 excelled in services, with five out of its seven SP industries having more rapid productivity growth than the EU-10. In the non-market sector productivity growth was virtually the same in the United States and EU-10, with small positive or negative numbers except for growth slightly above one per cent in EU-10 public administration.<sup>18</sup>

One of the most notable differences between the EU-10 and the United States

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18 The predominant theme of the previous literature on the EU productivity growth slowdown is to emphasize the role of market services in the shortfall relative to the United States. Among these papers are Uppenberg *et al.* (2010), Timmer *et al.* (2011), Inklaar *et al.* (2005), Van Ark *et al.* (2008), and Inklaar *et al.* (2007).

**Table 4: Annual Labour Productivity Growth Rates by Industry Group, EU-10, Selected Intervals, 1972-2015**

Industry	1972-95	1995-05	2005-15
<b>Total</b>	<b>2.31</b>	<b>1.26</b>	<b>0.63</b>
<b>Market</b>	<b>2.47</b>	<b>1.61</b>	<b>0.72</b>
<b>Commodities</b>	<b>3.11</b>	<b>2.26</b>	<b>0.95</b>
Agriculture	4.76	3.47	1.37
Mining	3.70	-0.72	-0.29
Manufacturing	3.46	2.87	1.84
Utilities	2.78	3.21	-1.38
Construction	1.12	-0.10	-0.30
<b>Services</b>	<b>1.69</b>	<b>1.23</b>	<b>0.64</b>
Wholesale & Retail	2.03	1.81	1.29
Transportation	3.44	2.46	0.42
Hotels & Restaurants	-0.53	-0.52	-0.58
Information & Communications	2.11	3.84	2.26
Finance & Insurance	1.49	2.14	1.14
Professions & Administrative	0.94	-1.03	-0.24
Arts & Entertainment	0.64	0.40	-0.51
<b>Non-market</b>	<b>0.60</b>	<b>0.26</b>	<b>0.19</b>
Real Estate	-0.40	-0.21	0.58
Public Sector	1.59	1.26	1.11
Education	0.72	-0.19	-0.70
Health	0.42	0.36	0.22

Source: KLEMS Database.

is the failure of the EU to mimic the 1995-2005 growth revival enjoyed by the United States. Yet the best-performing EU-10 industries during 1995-2005 were in most cases the same as in the United States, sufficient to create a correlation coefficient across industries of 0.71 between the 1995-2005 productivity growth rates in the EU vs. United States. The top-performing industries were similar — agriculture, manufacturing, information/communication, and finance/insurance. But in each of these cases EU growth fell short of U.S. growth, and in other industries the EU did poorly and lagged by a substantial margin, especially in wholesale/retail, hotels/restaurants, and professional/administrative. There is only a 0.08 correlation across industries between EU 1995-2005 growth and the *difference* by industry between United States and EU

growth.

After 2005 EU-10 productivity growth slowed to 0.63 per cent per year in the total economy, little different than the sluggish 0.87 per cent pace registered by the United States. The post-2005 slowdown in the United States was greater than in the EU-10, because the United States during 1995-05 had achieved faster growth. Fully ten of the 12 EU-10 market industries experienced slower growth after 2005. Only five of the 12 industries in the market sector registered productivity growth above 1.0 per cent after 2005, while six recorded negative productivity growth — three of these were CP industries and the other three were SP industries.

Because productivity growth in the EU-10 slowed both after 1995 and again after 2005, we can examine the industry composition of the slowdown most efficiently

by combining the two slowdowns. Accordingly the left column of Table 5 compares EU-10 productivity growth by industry for 2005-2015 with that for 1972-1995. Four of the 12 industries in the market sector experienced slowdowns of more than 3.0 percentage points, three of which were CP-industries (agriculture, mining, and utilities) while one was a SP industry (transportation services). Overall the average slowdown for the CP industries (-2.15 percentage points) was more than double the slowdown for the SP industries (-1.05 percentage points).

Almost all the industries in the non-market sector experienced slower productivity growth, although for most the declines were small because growth in the initial 1972-1995 interval was relatively slow. In fact there is a general tendency for the industries that grew the fastest in the initial 1972-1995 interval to have the largest growth slowdowns to 2005-2015. The correlation coefficient between 1972-1995 growth rates and the slowdown shown for the EU-10 market sector in Table 5 is -0.72 and rises to -0.78 when the non-market sector is included.

In our discussion of Table 1 above, we noted that for the total economy the EU-10 experienced almost exactly the same slowdown (-1.68 points) from 1972-1995 to 2005-2015 as the United States experienced from the earlier 1950-1972 period to 2005-2015 (-1.67 points). To further explore this close similarity between the two overall slowdowns, Table 5 adds an additional col-

umn that shows the change for each industry in U.S. productivity growth from 1950-1972 to 2005-2015. Several similarities stand out, including the large slowdowns in both columns for agriculture, manufacturing, utilities, and transportation services. The U.S. experienced greater slowdowns in retail/wholesale, hotels/restaurants, and information/communication. In the opposite direction the United States had no slowdown at all in mining, one of the worst-performing EU sectors, and the United States experienced an overall rise in productivity growth compared to a EU slowdown in finance/insurance and arts/entertainment.<sup>19</sup>

How closely related are the EU-10 vs. U.S. slowdowns shown in Table 5? Leaving aside the professional/administrative industry, the correlation coefficient in the market sector between the EU and U.S. slowdowns is 0.54 and the rank correlation is 0.70. When mining and arts/entertainment are removed the correlation rises to 0.81 and the rank correlation to 0.90. The major exception of mining can be explained by the development of the fracking revolution after 2005 in the United States but not in the EU-10. With the exception of mining we can conclude that the industrial composition of the EU and U.S. productivity growth slowdowns is highly correlated when the early and late intervals are compared as in Table 5.

The close correlation between the EU and U.S. slowdowns extends further to the close 0.79 correlation across industries in

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<sup>19</sup> The U.S. cell for professional/administrative is empty because data for that industry are missing for part of the 1950-1972 interval.

**Table 5: Labour Productivity Changes by Industry Group, Full Period  
Slowdowns for EU-10 and United States (percentage points per year)**

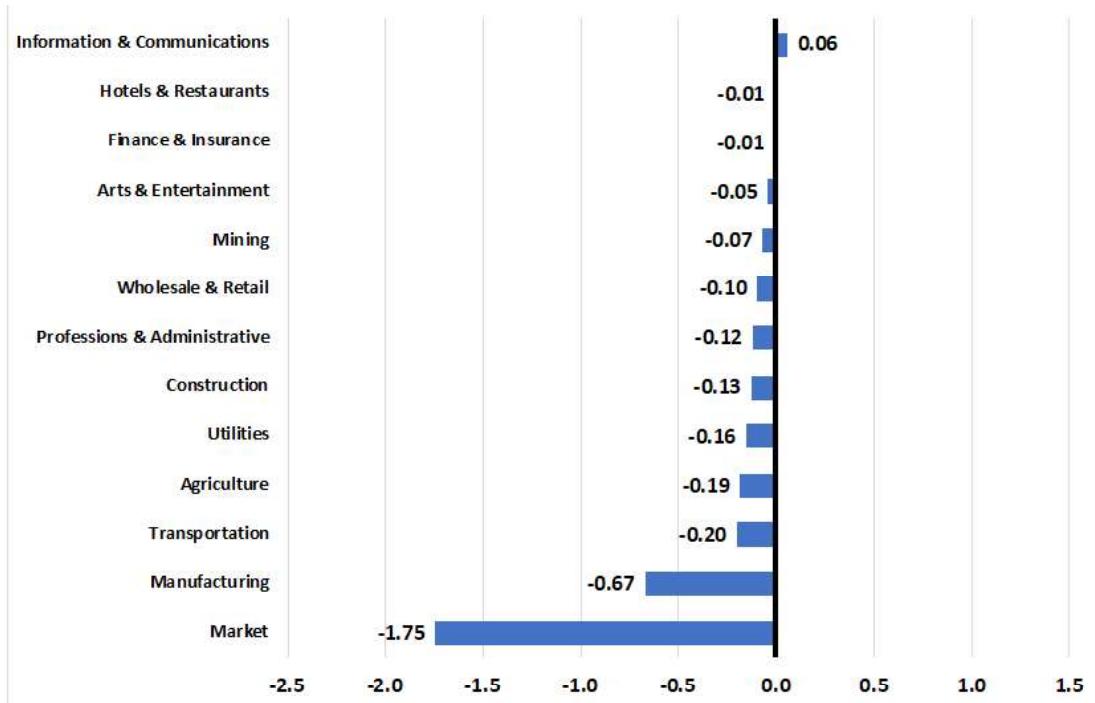
Industry	EU-10	United States
	1972-1995 to 2005-15	1950-72 to 2005-15
Total	-1.68	-1.67
Market	-1.75	-2.19
Commodities	-2.15	-2.13
Agriculture	-3.39	-3.63
Mining	-4.00	0.00
Manufacturing	-1.62	-1.51
Utilities	-4.16	-4.59
Construction	-1.41	-2.81
Services	-1.05	-1.29
Wholesale & Retail	-0.74	-2.76
Transportation	-3.02	-3.06
Hotels & Restaurants	-0.04	1.07
Information & Communications	0.15	-1.28
Finance & Insurance	-0.35	0.99
Professions & Administrative	-1.18	-
Arts & Entertainment	-1.15	0.99
Non-market	-0.41	0.81
Real Estate	0.98	-0.26
Public Sector	-0.47	1.26
Education	-1.41	-1.48
Health	-0.20	0.28

Source: KLEMS Database.

the productivity growth rate achieved during 1950-1972 for the United States with that recorded for the EU-10 during 1972-1995. This reflects the pattern that cross-industry differences in productivity growth in the earlier periods differed more than in the final interval, and that the industries that grew fastest in the earlier periods experienced the greatest slowdowns when the earlier periods are compared to the final period. Furthermore, four of the five fastest-growing EU-10 industries in 1972-1995 were producing commodities. For the United States the same four CP industries were among the six fastest growing industries. In both the EU-10 and in the United States the construction industry was the only CP industry that failed to achieve productivity growth in the top performing group.

Just as Chart 4 displayed the contribution by industry for the United States between the early 1950-1972 and late 2005-2015 periods to the slowdown in market sector productivity growth, so Chart 5 displays the same contributions for the EU-10 between its early 1972-1995 interval and 2005-2015. With the exception of professional/administrative, for which there are no early data for the United States, the list of the six most important industries contributing to the slowdown is the same for the United States and EU-10. The contributions are in roughly the same order, as evidenced by the remarkably high 0.85 correlation across industries in the contributions displayed in Chart 4 compared with Chart 5. This supports our theme that the overall slowdown from the early postwar years to the most recent decade was due

**Chart 5: Value-Added Weighted Contributions of Market Industries to Labour Productivity Growth Slowdown, EU-10, 1972-1995 to 2005-2015 Transition**  
 (percentage points per year)



Source: KLEMS Database.

to a retardation in technical change that affected the same industries by roughly the same magnitudes in the United States and in the EU-10. The most important difference is that wholesale/retail was in second rank for the United States with its contribution of -0.59 points, whereas that industry was in seventh place for the EU-10 with a much smaller contribution of -0.10 points.

### **Industrial Sector Behavior Within EU-10 Manufacturing and EU-U.S. Comparisons**

We now turn to the performance for the EU-10 of the 11 sub-industries within manufacturing, where productivity growth rates are shown for the three intervals in Table 6. In the initial 1972-1995 inter-

val productivity growth was robust across manufacturing, with eight of the 11 sub-industries reporting growth of more than 2.5 per cent. Only petroleum fell short, with growth below 1.0 per cent, which is interesting because the U.S. petroleum refining sector also suffered a severe growth slowdown after 1972. This similarity of slow productivity growth in the United States and EU-10 petroleum refining industry may reflect the influence of the oil price shocks of 1973-1975 and 1979-1981.

Growth in total EU-10 manufacturing declined modestly after 1995 from 3.46 per cent in 1972-1995 to 2.87 per cent in 1995-2005. The pattern of slower growth was quite uniform, as nine of the 11 sub-industries experienced slower growth, and only two (food and chemicals) experienced

**Table 6: Annual Labour Productivity Growth Rates by Industry Group, EU-10 Manufacturing, Selected Intervals, 1950-2015**

Industry Name	1972-95	1995-2005	2005-15
<b>Total Manufacturing</b>	<b>3.46</b>	<b>2.87</b>	<b>1.84</b>
Food	2.36	0.92	0.42
Textiles & Apparel	3.47	2.99	2.11
Wood & Paper	2.59	2.38	2.02
Petroleum	0.43	-0.39	-3.53
Chemicals	5.41	4.05	1.94
Rubber & Plastics	3.24	2.42	1.42
Metals	3.00	2.01	1.62
Electrical Machinery	5.47	4.78	2.95
Machinery NEC	2.66	2.86	0.97
Transportation Equipment	3.61	2.58	3.15
Other Manufacturing	1.31	2.82	1.12

Source: KLEMS Database.

a growth slowdown of more than 1.0 per cent. Two industries registered faster productivity growth, machinery n.e.c. and other manufacturing. Industries remained in roughly the same rank from fastest to slowest growing, with the correlation coefficient across industries of growth rates for 1972-1995 versus 1995-2005 a high 0.84.

There was a larger slowdown after 2005, from 2.87 to 1.84 per cent per year for total manufacturing. Four industries — petroleum, chemicals, electrical machinery, and machinery n.e.c. — experienced a slowdown of more than 1.8 percentage points. Only transportation equipment enjoyed an increase, albeit small, in productivity growth. Industries retained roughly the same rank from fastest to slowest growing, with a correlation coefficient of 0.82 across industries of growth rates for 1995-2005 and 2005-2015. The correlation between growth rates in the first and last periods is 0.75. However, there is no association between the cross-industry slowdowns after 1995 and after 2005, with a small correlation coefficient of -0.20.

We can extract from Tables 3 and 6 a

comparison of the EU-10 slowdown from the first (1972-1995) to last period with the U.S. slowdown from its first (1950-1972) to last period. On one hand, the slowdowns for total manufacturing are similar, -1.62 for the EU-10 and -1.51 for the United States, and these magnitudes are quite similar to the -1.67 and -1.68 slowdowns for the total economy over the same time comparison. However, the pattern is somewhat different, as several industries experience substantially greater slowdowns in the United States than in the EU-10, particularly petroleum. Food, textiles, machinery n.e.c., and other manufacturing also experienced substantially greater slowdowns in the United States. Partly offsetting these slowdowns are the totally different behavior of electrical machinery, which (despite a big slowdown from 1995-05 to 2005-2015) grew substantially faster in the final period than before 1972 in the United States, whereas growth for the EU-10 electrical machinery industry in 2005-2015 was slower than in 1972-1995. The correlation across industries for the early-to-late slowdowns is 0.43 for the 11 industries but

jumps to 0.73 when the electrical machinery industry is excluded.

## Was Slowing Innovation or Flagging Investment Responsible for the Slowdown?

In Charts 2 and 3 we decomposed labour productivity growth in our four intervals in both the United States and EU-10 into the respective contributions of MFP growth, capital deepening, and changes in labour composition. Now we look at these contributions by industry and focus on the early-to-late slowdowns that were previously illustrated for labour productivity growth in Charts 4 and 5. Panel A of Chart 6 shows contributions by industry for the market economy to the U.S. slowdown between 1950-1972 and 2005-2015. Green segments measure the contribution of MFP, purple segments the contribution of capital deepening, and gold segments the contribution of changes in labour composition. The industries are ranked in order of the MFP contributions, ranked from mining at the top with a positive 4.72 point contribution down to utilities with its -3.41 point contribution.

The total economy appears in the middle with a -0.85 point negative contribution of MFP growth. This contribution is almost exactly the same length as the purple bar indicating a -0.83 point negative contribution of capital deepening. The five top-listed industries with a positive MFP contribution all show a negative capital deepening contribution, and for mining the purple bar indicating a negative -4.70 point contribution of capital deepening almost exactly offsets the positive mining

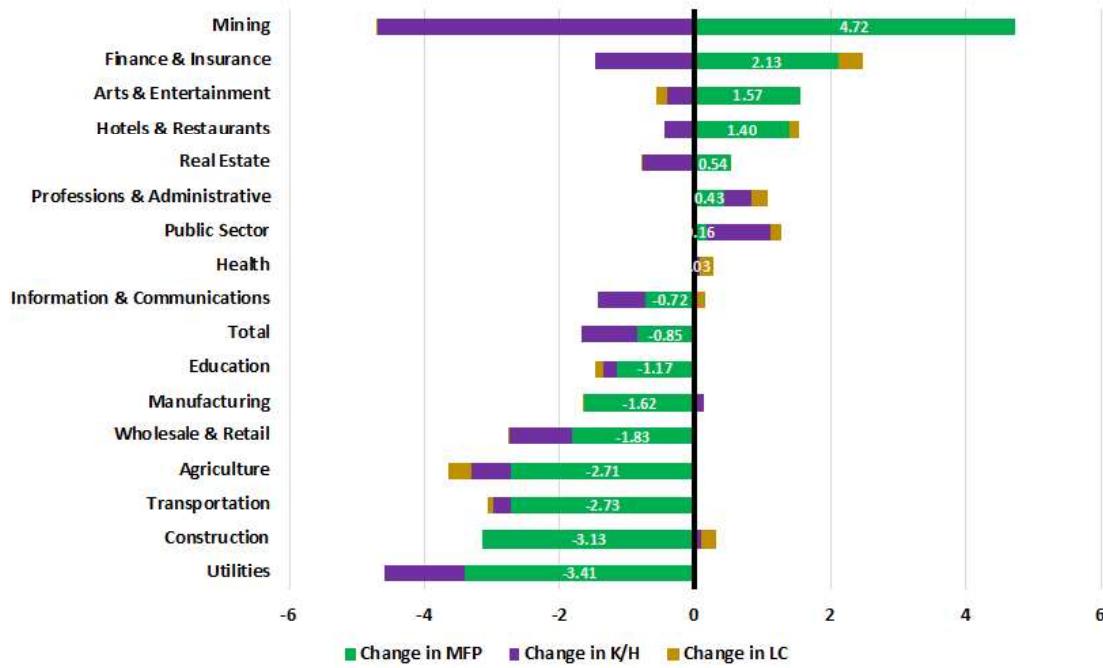
MFP contribution, resulting in a change in labour productivity growth of almost exactly zero (mining productivity growth in Table 2 was 2.97 per cent during 1950-1972 and 2.98 per cent during 2005-2015). Most of the industries at the bottom listed underneath the bar for the total economy display increasingly negative MFP contributions with small additional negative contributions of capital deepening.

Overall the industries are split on their MFP contributions, with eight registering positive contributions and eight recording negative contributions. The negative contributions are on balance larger and the industries more important (notably manufacturing and wholesale/retail), explaining why for the total economy the MFP contribution is on balance -0.85 per cent. A particularly important finding is that the slowdown of -1.51 points in manufacturing is overexplained by a decline of -1.62 points for the MFP contribution, with a 0.11 point positive contribution for capital deepening. As we shall see below, virtually all of the 11 manufacturing sub-industries had a negative MFP contribution to the overall slowdown, strengthening the case for a largely technological explanation. The contributions of changing labour composition are split evenly between positive and negative and range from a positive 0.35 for finance/insurance to a negative 0.33 in agriculture.

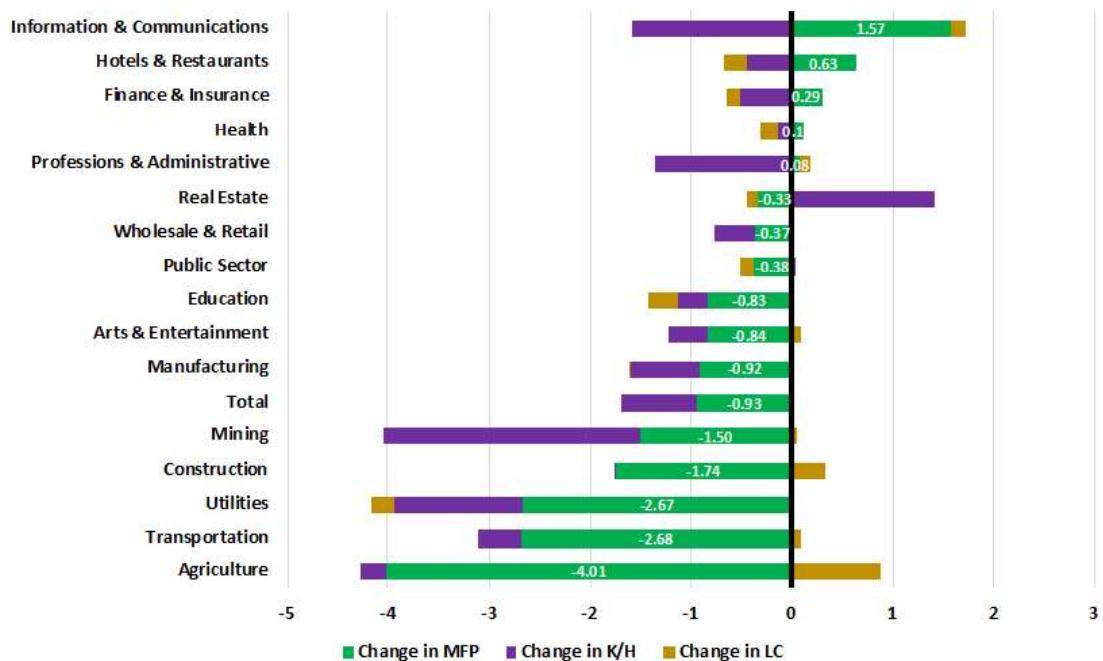
Panel B in Chart 6 displays in the same format the contributions to the EU-10 productivity slowdown from 1972-1995 to 2005-2015. Here there is a greater preponderance of industries with negative MFP contributions, 11 out of the 16 industries. Fully 14 of the 16 have negative

**Chart 6: Decomposition of Labor Productivity Change**

**Panel A: Decomposition of Labour Productivity Change for U.S. Total Economy, 1950-1972 to 2005-2015, Ranked in Order of Change in MFP Contribution**



**Panel B: Decomposition of Labour Productivity Change for EU-10 Total Economy, 1972-1995 to 2005-2015, Ranked in Order of Change in MFP Contribution**



Source: KLEMS Database.

capital deepening contributions. For the total economy the contribution of MFP of -0.93 points slightly exceeds that of capital deepening which is -0.77 points. The contribution of changing labour composition for the total economy is a negligible 0.02 points. The industry displayed as the top bar, information/communications, shows the same combination of a positive MFP contribution offset by a negative capital deepening contribution that we noted for mining in the case of the United States., but here the positive and negative numbers are less than half as large.

How similar are the United States versus EU-10 lists of industries experiencing the greatest slowdowns in the MFP contribution? Remarkably five of the bottom six industries are the same (although not in the same order) — agriculture, transportation, utilities, construction, and manufacturing. Mining appears in the bottom six on the EU-10 list while wholesale/retail appears in the bottom six on the U.S. list. The correlation of the MFP contributions across industries is 0.47 for all 16 industries but rises to 0.70 when mining is excluded.

We can carry out the same analysis of MFP vs. capital deepening contributions for the 11 individual sub-industries within manufacturing. For the United States all sub-industries except for electrical machinery and transportation equipment had negative MFP contributions between 1950-1972 and 2005-2015. The contributions of capital deepening are generally small and for total manufacturing is a slightly positive 0.11 points, so as pointed out above the MFP growth slowdown overexplains the labour productivity growth slowdown. The seven lowest-ranked industries all have

negative MFP contributions of greater than -3.0 percentage points, and the contribution of MFP in petroleum is an enormous -10.47 points. Capital deepening contributions are generally small. Thus manufacturing is the sector of the economy in which the case for a technological explanation of the productivity growth slowdown is the strongest.

For the EU-10 capital deepening plays a larger role in explaining the “early-to-late” slowdown within manufacturing. For total EU manufacturing the MFP contribution of -0.92 points and the capital deepening contribution of -0.68 points are sufficient to explain the productivity slowdown of -1.62 points, with a negligible contribution from labour composition. Nine of the 11 EU sub-industries had a negative MFP contribution and neither of the others had a significant positive contribution. Each of the 11 sub-industries had a negative capital deepening contribution, and the largest of these were -1.40 points in petroleum and -1.89 points in electrical machinery. It is notable that electrical machinery performed so poorly in Europe, in contrast to the United States where that industry was the only one to record a sizeable positive change in the MFP contribution.

Beyond the difference in electrical machinery, how similar between the United States and EU-10 were the sub-industries experiencing the worst slowdowns in the MFP contribution? Four of the worst six are shared in common — chemicals, petroleum, food, and machinery n.e.c. The correlation across sub-industries in the magnitude of the MFP contribution change is 0.67 for all 11, which rises to 0.75 when electrical machinery is excluded and to 0.82

when the metals sub-industry is also excluded. This compares to a correlation for the total economy from Panel A and Panel B of Chart 6 of 0.70 for the total economy when mining was excluded. Thus we can conclude that the process of a slower MFP contribution, which reflects largely a smaller impact of innovation, originated in roughly the same set of industries in the EU-10 as in the United States.

How closely related between the EU and United States are the industries making the largest contributions to productivity growth and the growth slowdown? The first row and first column of Table 7 report for the total economy a regression of productivity growth by industry in the EU-10 during 1972-1995 on U.S. productivity growth by industry during the earlier time interval 1950-1972. The constant is a significant 0.90 and the coefficient a highly significant 0.49. The data points and the regression line are plotted in Panel A of Chart 7, along with a 45 degree line that indicates equal growth rates. There are four industries on the right side of the diagram lying above the regression line and on or above the 45 degree line, indicating 1972-1995 EU-10 performance superior to that in the United States during 1950-1972 — namely, agriculture, manufacturing, mining, and transportation services.

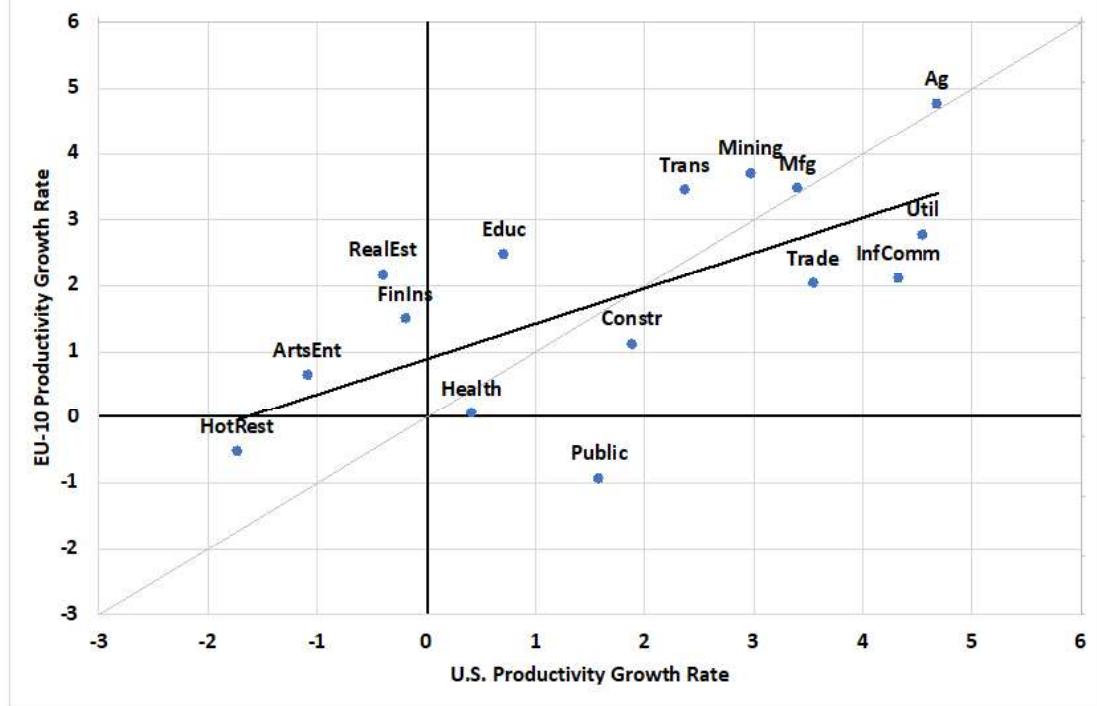
The second column of the top row in Table 7 reports that for the 11 sub-industries within manufacturing, the regression coefficient is negative rather than positive, although the relationship is weak. Removing the chemicals and electric machinery industries raises the  $R^2$  from 0.08 to 0.51 but does not change the negative coefficient within manufacturing.

In light of the fact that the United States enjoyed a productivity growth revival after 1995 but the EU did not, the second row of Table 7 asks whether, despite this divergence, there was a relationship between the faster growing and slower growing EU industries and their U.S. counterparts during the 1995-2005 interval. For the total economy in the first column the coefficient is a highly significant 0.48, indicating that on average EU industries during 1995-2005 grew roughly half as fast as in the United States Panel B of Chart 7 illustrates this relationship, showing that agriculture, manufacturing, and finance/insurance lie right along the regression line, with trade a bit below, while information/communication lies on the 45 degree line, indicating equal growth rates in the EU-10 and United States.

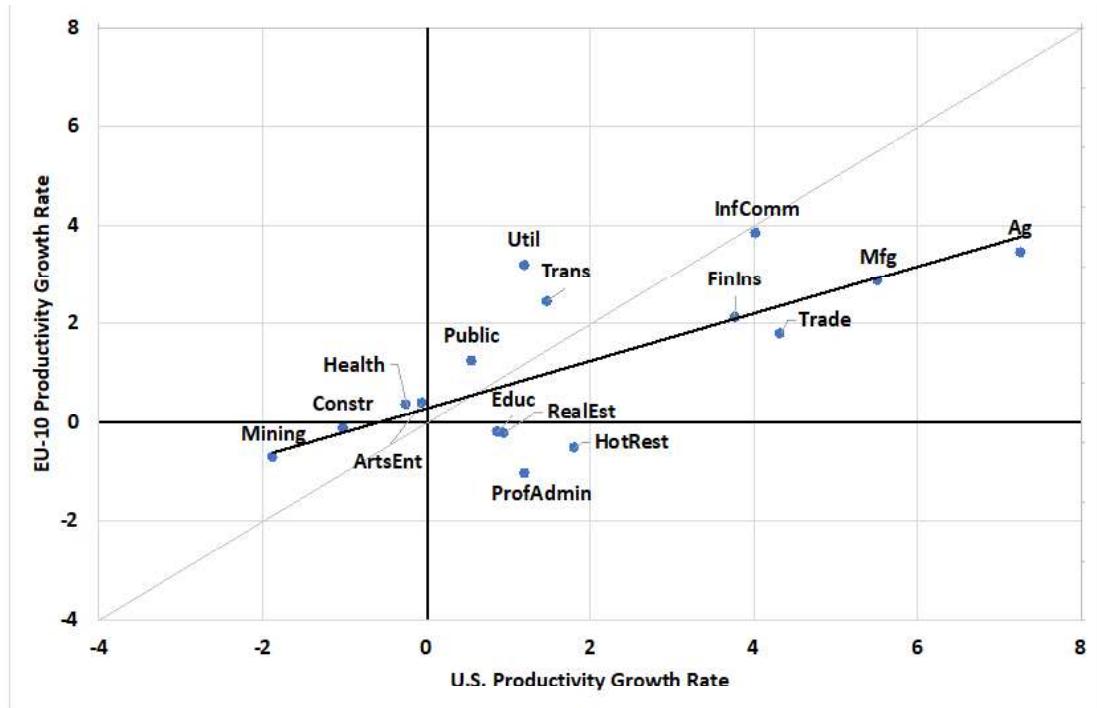
Finally, we have noted above that there is a relatively strong relationship between the industries in the EU-10 in the magnitude of its early-to-late growth slowdowns (from 1972-1995 to 2005-2015) and the industries in the United States in its early-to-late slowdown (1950-1972 to 2005-2015). For the total economy the coefficient is a significant 0.49. For manufacturing the coefficient is an insignificant 0.16, but this rises to a highly significant 0.34 with a  $R^2$  of 0.89 when the electrical machinery, other manufacturing, and chemicals industries are excluded. The relationship for the total economy is plotted in Chart 8, showing that six industries lie along the 45 degree line, indicating almost exactly the same extent of the early-to-late change in productivity growth in the EU-10 as in the United States — agriculture, manufacturing, utilities, transportation services, edu-

Chart 7: Regression of EU-10 Labour Productivity Growth on U.S. Labour Productivity Growth (Two Periods)

Panel A: Regression of EU-10 1972-1995 Labour Productivity Growth on U.S. 1950-1972 Labour Productivity Growth



Panel B: Regression of EU-10 1995-2005 Labour Productivity Growth on U.S. 1995-2005 Labour Productivity Growth



Source: KLEMS Database.

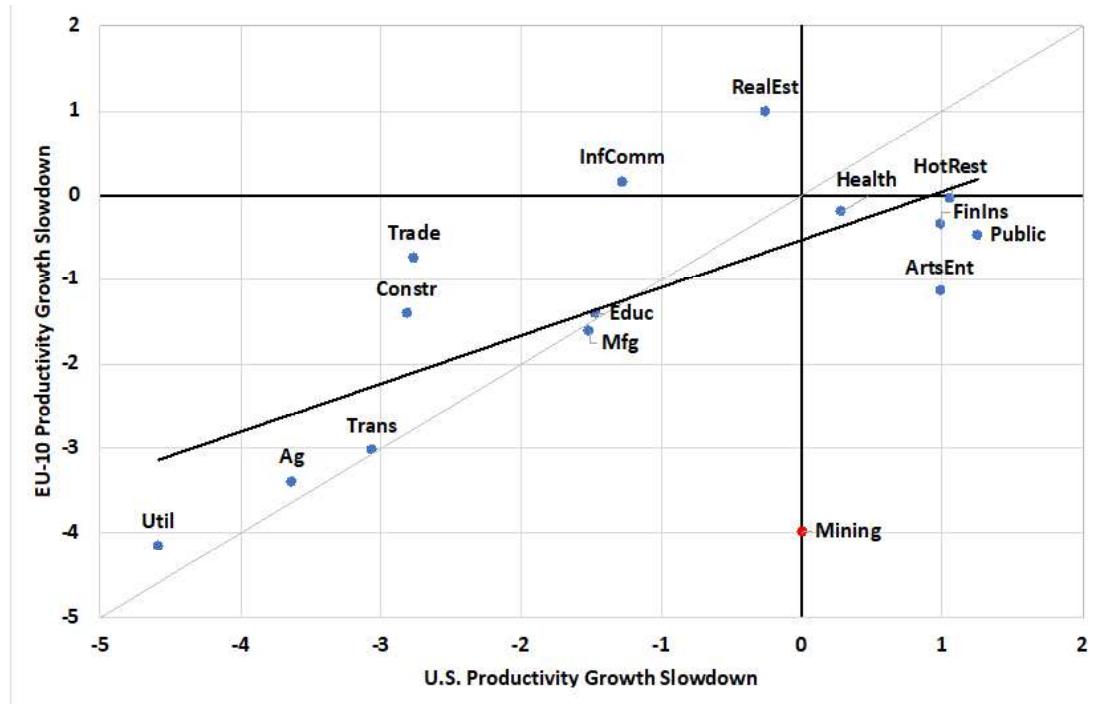
**Table 7: Regressions of EU-10 Growth on U.S. Growth by Industry, Selected Intervals**

	U.S. Variable	All Major Industrial Sectors		Manufacturing Sub-Industries		All Selected Exclusions*
		Coef.	Prob > t	Coef.	Prob > t	
		Constant	NOBS	Adj R <sup>2</sup>	Adj R <sup>2</sup>	
a) EU-10 1972-95 on U.S. 1950-72	U.S. Variable	0.49	0.01	-0.32	0.20	-0.36 0.02
	Constant	0.90	0.05	4.31	0.00	3.93 0.00
	NOBS		15		11	9
	Adj R <sup>2</sup>		0.41		0.08	0.51
b) EU-10 1995-2005 on U.S. 1995-2005	U.S. Variable	0.48	0.00	0.07	0.49	0.18 0.00
	Constant	0.30	0.44	2.17	0.01	1.85 0.00
	NOBS		16		11	9
	Adj R <sup>2</sup>		0.49		-0.05	0.78
c) EU-10 Full Slowdown on U.S. Full Slowdown	U.S. Variable	0.49	0.02	0.16	0.18	0.34 0.00
	Constant	-0.84	0.05	-1.32	0.02	-0.53 0.04
	NOBS		15		11	8
	Adj R <sup>2</sup>		0.31		0.10	0.89

Note: \*Selected manufacturing exclusions include Chemicals and Electrical Machinery for panel a); Petroleum and Chemicals for panel b); Electrical Machinery, Other Manufacturing, and Chemicals for panel c). Data for the “Professions & Administrative” industry are unavailable for the U.S. from 1950-72.

Source: KLEMS Database.

**Chart 8: Regression of EU-10 1972-1995 to 2005-2015 Productivity Slowdown on U.S. 1950-1972 to 2005-2015 Productivity Slowdown (percentage points)**



Source: KLEMS Database.

cation, and health.

These results indicate that, at least for the total economy, if in 1972 one had known the rate of productivity growth by industry achieved in 1950-1972 for the United States, one would have been able to do a quite a good job of predicting productivity growth by industry in the EU-10 in the subsequent 1972-1995 period. There was also a significant positive relationship for the total economy between EU and U.S. growth by industry within the 1995-2005 interval, as well as in the magnitude of the early-to-late interval productivity growth slowdown. The results are much weaker within manufacturing and indeed show a negative relationship between the U.S. 1950-1972 growth rates and those in the EU-10 for 1972-1995. But even for manufacturing there is quite a strong positive relationship across industries in the magnitude of the early-to-late slowdown when three outlier industries are excluded.

## A Consideration of Alternative Hypotheses

Throughout the article we have pointed to the high correlations between the United States and EU-10 in the industry composition of productivity growth and its slowdown, both within and across time periods. This is consistent with a technological interpretation of the growth slowdown, that industry-specific innovations were achieved in common across the Atlantic and determined the pace of productivity growth in each industry, with Europe's adoption of technologies lagging roughly 20 years behind the United States from the early post-war years to 2005. The strong role of MFP

in the growth-accounting decomposition of the sources of labour productivity growth is also consistent with a prominent role in the slowdown for a waning of the impact of earlier innovations. To use a frequently-used analogy, "the low-hanging fruit had been picked." In another analogy, the level of productivity when plotted on a logarithmic scale has the appearance of an "S" on its side, the so-called "S curve," rising slowly at the beginning, then rapidly in the middle, and more slowly at the end. This phenomenon was illustrated for numerous products and industries by Lapp (1973).

In a phenomenon as important and complex as the productivity growth slowdown, other factors may have also made a contribution. We consider briefly reverse feedback from innovation to investment and mismeasurement of output. We then examine two potential explanatory factors beyond innovation that may have played a role in the convergence of the EU-10 productivity level to the U.S. level between 1995 — the role of education and of the differing trajectory of hours per employee.

The standard growth accounting decomposition of labour productivity growth between MFP and capital deepening implicitly treats the sources of changes in MFP and of capital deepening, i.e., growth in capital per labour hour, as two independent sources of growth. Innovation, including large and small inventions as well as incremental tinkering that makes previous inventions more efficient, are assumed to be the drivers of MFP growth. Factors such as interest rates and taxation are usually cited as the major determinants of the level of investment that in turn drives the growth in capital per labour hour.

However this decomposition ignores the response of capital per hour growth to productivity growth. In the standard Solow growth model, long run capital per hour growth equals output per hour growth and the capital-output ratio is constant. Thus anything that reduces growth in output per hour, including a diminished impact of innovation or a slowing rate of change of educational achievement, will reduce investment and cause slower growth in capital per hour. This reverse feedback from innovation to investment can occur, so that the split between MFP growth and changes in capital deepening as sources of productivity growth tends to underestimate the importance of slowing innovation. In this context we noted above that the 2005-2015 slowdown in U.S. productivity growth was led by a sharp slowdown in MFP growth during 2005-10 while capital deepening continued at the previous pre-2005 rate, while during 2010-15 capital deepening growth followed along with a sharp plunge to a negative value.

Measurement error is sometimes suggested as an explanation for declining productivity growth. The dominant role of commodity-producing industries in causing the U.S. post-1972 slowdown and 1995-2005 revival, together with their disproportionate role in the overall EU-10 slowdown, leads to skepticism about a measurement explanation of the trajectory of productivity growth over the postwar period. Of our five commodity-producing industries — agriculture, mining, manufacturing, utilities, and construction — the first four are considered relatively well measured as they produce tangible objects such as bushels of wheat, tons of coal, gallons

of refined petroleum, and kilowatt hours of electricity. Construction is the exception and has long been considered “hard to measure” due to its output deflators based on input costs. Assessing the manufacturing sector as relatively well measured is subject to the qualification that price indexes for manufactured goods have long been subject to an upward bias, but this bias is relatively consistent without prolonged episodes of worsening or improving bias. To explain the postwar trajectory of productivity growth in commodity-producing industries by measurement error would require that error to be absent during 1950-1972, emerge after 1972, disappear between 1995 and 2005, and then become even worse after 2005 than it was during 1972-1995.

While commodities dominated the post-1972 U.S. slowdown and 1995-2005 revival, as well as the post-1995 EU slowdown, both services and commodities have contributed roughly equally to the post-2005 slowdown on both sides of the Atlantic. Since output in several service sectors is hard to measure, could mismeasurement explain the more recent post-2005 slowdown? This question has been carefully considered in the recent literature on the United States, particularly in papers by Byrne *et al.* (2016) and Syverson (2017). They both conclude that the role of mismeasurement, primarily in the undercounting of free internet services, cannot plausibly be large enough to explain more than a small fraction of the post-2005 U.S. slowdown. The details of their arguments go beyond the scope of this article, but we might add that several of the industries with the largest post-2005 slowdowns, such

as agriculture and transportation services, and within manufacturing petroleum refining and rubber/plastics, are relatively easy to measure, whereas several hard-to-measure sectors such as education and healthcare services experienced either small slowdowns after 2005 or, in the case of U.S. healthcare, an actual increase in productivity growth.

Turning to the explanation of European convergence to the U.S. productivity level between 1950 and 1995, the most convincing reason is the lag behind the United States in the adoption by Europe of the major innovations that had propelled the United States by 1950 to double the level of labour productivity as the EU-10 average. It is plausible that other explanations also made a contribution to the European convergence. One possibility is educational attainment, which also lagged in the EU-10 substantially below the U.S. level. Chart 9 shows average years of school completed during 1950-2010 for the United States as the upper line and the average for the five largest members of the EU-10 (France, Germany, Italy, Spain, U.K., making up 85 per cent of EU-10 GDP) as the lower line labelled “EU-5”.

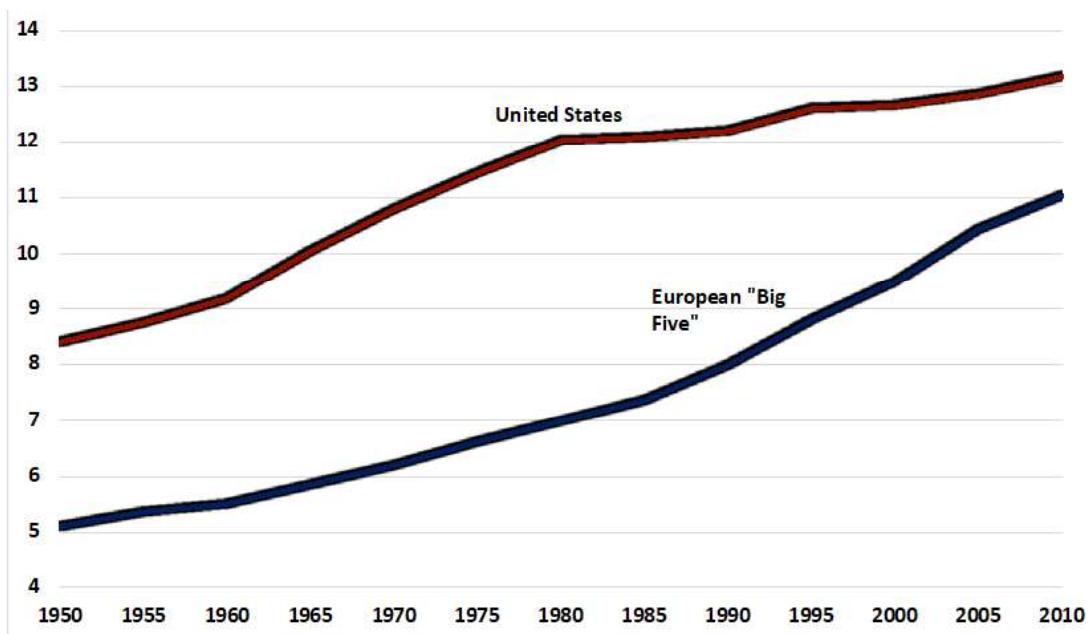
The trajectory of the lines in Chart 9 weakens the case for a major role of education in the European convergence. By far the period of most rapid European catch-up of the productivity level occurred during 1950-1972, but Chart 9 shows that the gap between the United States and the EU-5 widened from 3.3 years in 1950 to 4.8 years in 1975 and continued to widen further to 5.2 years in 1980. Yet by then the level of productivity in Europe had completed most of its convergence, reaching 100 per

cent of the U.S. level in 1989. The catching up of the EU-5 educational level occurred between 1980 and 2010, with the gap declining from 5.2 years in 1980 to 2.2 years in 2010. Yet the level of European productivity relative to the United States was actually lower in 2010 than in 1980. One aspect of the education hypothesis does, however, appears suggestive, and this is the role of the slow growth of U.S. educational achievement in 1995-2010 in contributing the slow U.S. productivity growth after 2005.

Another hypothesis that has been suggested to explain the European convergence to the U.S. productivity level is the decline in hours per employee illustrated in Chart 10. Over the period 1950-2015 hours per employee in the EU-10 declined sharply from 2250 hours to 1560 hours, a (log) decline of 37 per cent. In contrast hours per employee in the United States declined only from 2020 to 1780, a (log) decline of 12 per cent. Hours per employee in Europe were higher than in the United States from 1950 to 1975 and have been lower since 1975. The hypothesis of diminishing returns to added hours of work by an individual employee suggests that declining hours should raise productivity. If all else were equal, productivity in the EU-10 should have caught up to the U.S. level in 1975 and exceeded it thereafter. But other factors were not equal — Europe caught up to the U.S. productivity level in 1989 and exceeded it until 2000.

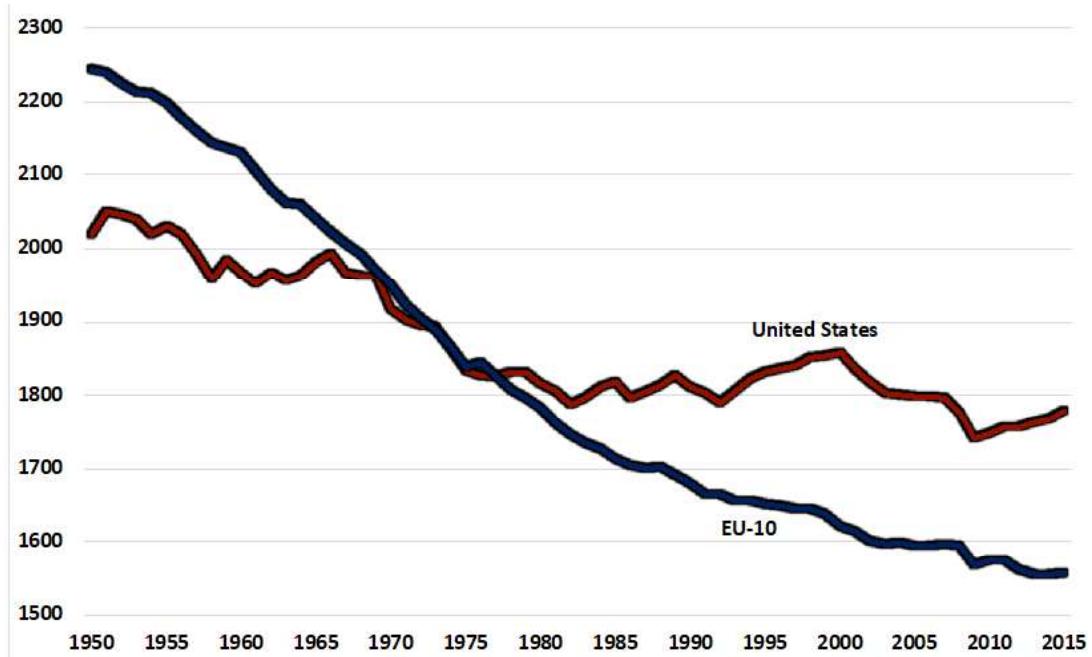
This section has thus far ignored the big exception to the result that Europe lagged 20 years behind, and this was the fact that U.S. productivity growth surged ahead during 1995-2005 without any echo

**Chart 9: Average Years of Schooling Completed by Population Aged 15 and Over, United States vs. Geometric Average of European "Big Five," 1950-2010**



Source: Five-year data on average years of total schooling for population aged 15 and up from Barro-Lee Educational Dataset, last updated July 2, 2018. The European "Big Five," comprised of France, Germany, Spain, Italy, and the United Kingdom, stably account for approximately 85 per cent of the EU-10 GDP between 1950 and 2015.

**Chart 10: Total Hours Worked per Employed Person, United States vs. EU-10, 1950-2015**



Source: Conference Board Total Economy Database. Hours per Employee for the EU-10 are calculated as the sum of total divided by the sum of total employed persons for the relevant countries.

effect in Europe either at the same time or ten years later. As a result the level of European productivity relative to the United States fell back from a peak of 106 per cent in 1995 to just 86 per cent in 2015. Chart 7 Panel B above plots the 1995-2005 growth rate of each major European industry against its American counterpart. The correlation across industries is high but on average each European growth rate is about half of the corresponding U.S. growth rate.

The consensus in the American literature is that the 1995-2005 revival in U.S. productivity growth was driven by both an increase of investment in information-communication technology (ICT) hardware and the effect of ICT hardware and software in industries that are heavy users of ICT (Oliner and Sichel, 2000). Europe failed to achieve the same productivity gains, and this is evident above in the much slower rate of productivity growth in the electrical machinery industry (home of ICT hardware) in Table 6 for the EU-10 than in Table 3 for the United States. We have carried out a detailed analysis of the differing contribution of ICT hardware and software to productivity growth in the EU-10 as compared to the United States, to be published in the next issue of this journal.

## Conclusion

This article examines the industry origins of the slowdown in labour productivity growth for the United States going back to 1950 and for the EU-10 back to 1972. A novel contribution of the article is to merge several different KLEMS data sets and perform a year-by-year aggregation across Eu-

ropean countries that allows us to analyze aggregate and industry productivity performance in the EU-10 in contrast to previous studies which limited their analysis to an array of individual countries.

As suggested by Shackleton (2013) and a large previous literature, productivity growth in the United States soared between 1920 and 1972 as a result of key inventions such as electricity, the internal combustion engine, chemicals and plastics, information and communications, and an expansion of infrastructure. Due to the disruption of the two world wars and the interwar period, Europe missed out on many of the benefits of this wave of innovation, in 1950 having a ratio of its productivity *level* to the United States of only 50 per cent. Europe rapidly caught up in 1950-1972, by 1972 reaching a level ratio of 81 per cent, and in 1972-1995 more than caught up, reaching 106 per cent of the U.S. level in 1995.

From 1972-1995 the characteristics of EU-10 productivity growth were surprisingly similar both in overall pace and also in industry composition to that achieved by the United States in the prior 1950-1972 time period. A novel aspect of the article is to take the 1972-1995 period in the EU-10 as equivalent to the 1950-1972 interval in the United States and to calculate an “early-to-late” slowdown from these two different starting points to a common end interval, the decade between 2005 and 2015.

Contrary to the “Eurosclerosis” literature that laments European shortcomings in the scope and application of innovation and structural arthritis in its product and labour markets, one of the most striking results of this article is that the slow-

down in EU-10 productivity growth from the 1972-1995 average growth rate to 2005-2015 was exactly the same (-1.68 percentage points) as the slowdown in U.S. productivity growth from its 1950-1972 average growth rate to 2005-2015 (-1.67 percentage points).

Even more striking about this “early-to-late change” is that there is a correlation coefficient of 0.81 across industries between the United States and EU-10 in the magnitude of their growth slowdowns. Thus the productivity growth slowdown is a trans Atlantic disease, not only in its overall magnitude but in the composition of industries making the biggest contributions. This supports our overall theme that the productivity growth slowdown from the early postwar years to the most recent decade was due to a retardation in technical change that affected the same industries by roughly the same magnitudes in the United States and in the EU-10. From the early postwar years until 2005 the EU-10 can be characterized as lagging about 20 years behind the United States in its adoption of technology.

We emphasize the distinction between commodity-producing industries and those producing market services. In both the United States and EU-10, the early-to-late slowdown was more than twice as large in commodities as in services. This dominant role of commodities in driving the slowdown on both sides of the Atlantic reflects the fact that in the early periods (1950-1972 for the United States and 1972-1995

for the EU-10) productivity growth in commodities was faster and thus had further to fall. This reflects the role of inventions and innovations earlier in the 20<sup>th</sup> century that had a greater impact on commodity-producing industries than those producing market services.<sup>20</sup>

The best-known difference between productivity behavior in the United States and Europe, going beyond Europe’s catch-up lag between 1950 and 1995, is the failure of Europe to enjoy a productivity growth revival during 1995-2005 as did the United States. We show that there was a high correlation across industries between the United States and EU-10 in 1995-2005 growth rates, indicating that the industries that did best in the United States also did best in the EU-10. The problem was that for all the best-performing EU industries the productivity growth rate was about half of their U.S. counterparts during 1995-2005.

We carry out a sources-of-growth calculation which decomposes labour productivity growth into the respective contributions of multi-factor productivity (MFP), capital deepening, and changes in labour composition. For the United States MFP makes the dominant contribution to the post-1972 productivity growth slowdown and 1995-2005 revival, while MFP and capital deepening jointly share responsibility for the post-2005 slowdown. In the EU-10 the contributions of MFP and capital deepening are evenly divided in explaining the slowdown. To the extent that the MFP contri-

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20 The analysis of the Canadian productivity growth slowdown by Sharpe and Tsang (2018) finds many patterns similar to those highlighted in this article, including the major role of manufacturing.

bution measures the impact of innovation, we could conclude that flagging innovation deserves half the blame for the early-to-late slowdown in both the United States and the EU-10. The high correlation between the United States and EU-10 in the list of industries contributing the largest early-to-late slowdowns in the MFP contribution also support the theme of a common cause, the diminishing impact and depreciation of the innovations that had driven early post-war growth, particularly in the commodity-producing industries.

But it would be a mistake to limit the role of innovation to the MFP contribution. As suggested by the long-run dynamics of the standard Solow growth model, reductions in growth of output per hour, including those due to slowing innovation, simultaneously diminish capital deepening's contribution to productivity. Thus while the contribution of MFP to the early-to-late productivity growth slowdown is 50 per cent of the total in the United States and 55 per cent for the EU-10, the true contribution of flagging innovation is greater than that, perhaps three-quarters. The case for a technological explanation is particularly strong in U.S. manufacturing, where

the early-to-late slowdown in nine of 11 subindustries is dominated by a declining MFP contribution, and where for the manufacturing sector total MFP overexplains the overall decline in labour productivity growth.

This article is only a start at the enormous task of understanding the slow rate of productivity growth experienced on both sides of the Atlantic since 2005. We have emphasized the role of MFP and innovation, as well as the dominant role of the commodity-producing industries in driving the earlier slowdowns and 1995-2005 U.S. revival. Further insight into the sources of the productivity slowdown will need to be fought in the trenches of detailed studies of individual industries, and the research reported here has helped to point to those particular industries that are most in need of further insight and evaluation. This process will begin with a second article in the next issue of this journal on the role of the production and use of information-communication technology (ICT) equipment in the United States and EU-10 in achieving productivity growth in the aggregate and at the level of individual industries.

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# Online Appendix to “The Industry Anatomy of the Transatlantic Productivity Growth Slowdown: Europe Chasing the American Frontier”

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## Datasets Utilized

The vintages of the annual data used in this project were downloaded between May, June, and early July of 2018, and consist of the 2012 and 2017 releases of the EUKLEMS datasets. These data includes quantities, indices, and pre-calculated growth rates of output, capital, labor, and productivity, among other variables. With the exception of value added and a handful of indices (usually labor and capital services), labor productivity and growth rate data generally start post-1995 in the 2017 release. However, these data were also available in the 2012 releases, which estimated values back until 1970. To gain a full picture of the data for each country and industry back us far as possible, it was necessary to link the older release of the KLEMS from

2012 with the 2017 dataset.

Towards the end of July, EUKLEMS revised the 2017 release, in the process eliminating many pre-1995 datapoints. Since we downloaded the data prior to this revision, we have retained many of the now-missing pre-1995 values from the 2017 release, though these are likely available to some extent in the 2012 releases.

## Merging the KLEMS Data Old to New

The primary method of merging was ratio linking, which was used for merging indices and quantities. For each variable in a given industry and country, we took the earliest value available in the 2017 data and identified the observation in the older dataset corresponding to the same variable.

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<sup>1</sup> The main article is available at <http://www.csls.ca/ipm/37/Gordon.pdf>.

We then computed the ratio of the 2017 datapoint to the 2012 datapoint for that year and multiplied all prior observations by this ratio. The consequence of using this procedure was that growth rates were preserved across the old and new data without any jumps or discontinuities at the point of merging.

In the case of pre-calculated growth rates, datapoints were simply appended. That is, if time  $t$  were the last year that the growth rate for a variable was available in the 2017 data, then at time  $t-1$  and earlier, the growth rates for 2012 were used without any transformation. This method of appending growth rates is equivalent to ratio-linking indices, since ratio-linking ultimately multiplies the earlier subset of data by a uniform constant, preserving growth rates.

## Growth Accounting and Capital/Hour Contributions

The EUKLEMS data provide a handful of pre-calculated growth rates in its releases. These include:

1.  $VA\_Q$ , growth rate of real value added;
2.  $VAConTFP$ , contribution of TFP growth to real value added growth;
3.  $VAConLC$ , contribution of labor composition growth to  $VA\_Q$ ;
4.  $VAConH$ , contribution of hours growth to  $VA\_Q$ ;
5.  $VAConKIT$ , contribution of ICT capital services growth to  $VA\_Q$ ;
6.  $VAConKNIT$ , contribution of non-ICT capital services growth to  $VA\_Q$ ;
7.  $VAConK$ , contribution of capital ser-

vices growth to  $VA\_Q$ , which is the sum of  $VAConKIT$  and  $VAConKNIT$ ;

8. and  $LP1\_Q$ , the growth rate of value added per hour as calculated by the sum of contributions

These contributions to value added per hour are governed by the following equation:

$$VAQ_t = VAConTFP_t + VAConLC_t \\ + VAConH_t + VAConKIT_t \\ + VAConKNIT_t \quad (1)$$

Let  $s^{IT}$  be the share of ICT capital services in production,  $s^{NIT}$  the share of non-ICT capital,  $y$  value added growth,  $lc$  labor composition growth,  $h$  hours growth,  $k^{IT}$  ICT capital growth, and  $k^{NIT}$  non-ICT capital growth. Then, this equation can also be written as:

$$yt = tfpt + (1 - s^{IT} - s^{KIT}) (lc_t) \\ + (1 - s^{IT} - s^{KIT}) (ht) \\ + s^{IT} k_t^{IT} + s^{NIT} k_t^{NIT} \quad (2)$$

Extensive  $VAConKIT$  and  $VAConKNIT$  data were not available for the U.S., so we primarily utilized  $VAConK$  by adding together  $VAConKIT$  and  $VAConKNIT$ . For consistency, we also did this with the Europe data. Because of the identity above, this equation can be simplified to:

$$yt = tfpt + (1 - s) (lc_t) \\ + (1 - s) (ht) + sk_t \quad (3)$$

where  $s$  is defined so that  $sk_t = s^{IT}k_t^{IT} + s^{NIT}k_t^{NIT}$ .

On the other hand,  $LP1\_Q$  (or  $lp$ ), which is value added per hour, can be written as:

$$\begin{aligned} LP1Q_t &= lp_t = y_t - h_t = tfpt_t \\ &\quad + (1-s)(lc_t) + (1-s)(h_t) \\ &\quad + sk_t - h_t = tfpt_t + (1-s)(lc_t) \\ &\quad + s(k_t - h_t) \\ &= VAQ_t - h_t = VAConTFP_t \\ &\quad + VAConLC_t + s(k_t - h_t) \end{aligned} \quad (4)$$

Concretely, labor productivity growth is TFP growth + the contribution of labor composition + the contribution of capital per hour, i.e. capital's share multiplied by the growth rate of capital less the growth rate of hours. The contribution of capital per hour will be denoted by  $ConK/H$ .

One way to calculate  $ConK/H$  is to use nominal expenditure on labor and capital to retrieve labor's share, multiply the contributions of hours by  $\frac{s}{1-s}$ , and subtract this from  $VAConK$ . However, since  $LP1\_Q$ ,  $VAConTFP$ , and  $VAConLC$  are already given by KLEMS, we can simply calculate  $ConK/H$  as a residual. That is,

$$\begin{aligned} LP1Q_t - VAConTFP_t \\ - VAConLC_t &= ConK/H_t \end{aligned} \quad (5)$$

We indeed employ this method in the data to calculate the contribution of capital per hour. Not only does this satisfy the identity above and allow the given contri-

butions to add up to labor productivity, it also prevents any error related to computing  $ConK/H$  by hand using labor's share.

## Calculating Earlier $LP1\_Q$ Values

There are two labor productivity variables of interest available in the KLEMS data: “ $LP1\_Q$ ” and “ $LP\_I$ ” — while the former is a growth rate calculated bottom-up as a sum of contributions, the latter is an index that directly divides value added by the hours index. The former is available only in the 2017 release, while the latter is available in both the 2012 and 2017 datasets. Since this project is concerned with breaking down labor productivity growth into its components, we utilize  $LP1\_Q$  instead of  $LP\_I$ .

However, since  $LP1\_Q$  is unavailable in the 2012 data, we use the growth of the  $LP\_I$  index to proxy for any earlier years where  $LP1\_Q$  is unavailable — we append the growth rate of  $LP\_I$  to any data points prior to the earliest year where  $LP1\_Q$  is available.

## A Note on Anomalous UK Data

Upon a cursory observation of the UK KLEMS series for  $LP1\_Q$ , the year 1995 sticks out as an anomaly: the data source has labor productivity growth for the total economy listed at 23.5 percent, mining at 58 percent, and much of manufacturing above 15 percent. Although this result is likely due to an error in the original dataset, the data cannot be properly corrected if the source of that error is unknown. To correct for this problem, we cal-

culate the level of UK labor productivity in 1995 as the average of the values in 1994 and 1996.

## Aggregating the Commodities and Services industries

The KLEMS data are divided into two types of industries: commodities producing, alphanumeric industries A through F (Agriculture through Construction) and services producing industries G through S (Wholesale & Retail through Arts & Entertainment). To examine trends within both of these types of industries, we create aggregates for “Commodities” and “Services” by combining data from different subindustries into a single aggregate. In the case of nominal variables like gross output and value added, we simply add the values of each sub-industry. For indices and growth rates, we compute a weighted sum of the values of each sub-industry’s index or growth rate, where the weights are the shares of nominal value added of that industry in the entire value added of an aggregate. For example, the weight for the commodities producing “Agriculture” industry would be the value-added of Agriculture divided by the sum of value added for industries Agriculture through Construction, i.e. the total value-added of commodities.

## Creating the EU-10 Aggregate

To examine productivity behavior in a European aggregate, we use the same weighting technique as described above for Commodities and Services. In this case, the source of our weights are the real

PPP-adjusted GDPs of European countries, taken from the Conference Board Total Economy (TED) database, divided by the sum of those GDPs. We utilize a procedure of moving weights; since the data for different European variables start at different times, we take account of whether those countries are available in the dataset before assigning weights. For example, for the year 1974, only Germany, Italy, and the UK have data available for TFP growth. Because of this, we take the weight for Germany in 1974 to be the GDP for Germany divided by the sum of the GDPs of Germany, Italy, and the UK (rather than the entirety of the EU-10). As more countries enter into the dataset, we incorporate these new countries into the weights: when the Netherlands enters the dataset in 1980, for example, the weight for Germany is the GDP for Germany divided by the sum of the GDPs of Germany, Italy, the UK, and the Netherlands.

## European Value Added

Although it is straightforward to convert growth rates or indices to aggregates with the TED GDP weights, calculating nominal value added poses a challenge, as the EU KLEMS country-level datasets are all in terms of millions of national currency. To circumvent this issue, we used the TED GDP data as representative of the KLEMS Total Economy aggregate (“TOT”) and normalized each country’s industry’s value-added to TED PPP units.

To calculate PPP adjusted value added for country  $j$  and industry  $i$ , we took the industry’s share of TOT value added and multiplied it by the TED GDP for that

country:

$$VA_{i,j}^{adj} = \frac{VA_{i,j}^{KLEMS}}{VA_{TOT,j}^{KLEMS}} GDP_j^{TED}$$

Then calculating aggregate value-added for the EU-10 only required summing up the VA terms of each individual country.

## Extending the US Further: The WorldKLEMS Dataset

Although EUKLEMS mostly has U.S. growth rates back until 1977 (and some nominal indices back to 1970), a dataset from Dale Jorgensen and his collaborators on the WorldKLEMS website provides detailed data on the US back until 1947 in a similar format to the EUKLEMS data. We use the 2013 release of the data; the vintage was downloaded in mid-July of 2018. The range of this data is from 1947-2010. Instead of linking these data directly to the 2017 release of EUKLEMS, we first linked the earliest data in the 2017 release to the

earliest points in the 2012 release, and then linked the WorldKLEMS data to the earliest point of the 2012 data.

The primary limitation of this WorldKLEMS data is that the industry categories use an older revision of the ICIS (Rev 3), while the EUKLEMS data uses Rev 4. Hence, we have linked older industry categories into the newer ones. Table A1 details those re-classifications of data — some were left unlinked, while others were formed by aggregation. Aggregation of smaller industries into larger ones was done in the same way as the commodities and services aggregates discussed above, using value added weights for indices and growth rates and direct addition for nominal quantities.

The only industries that were could not be successfully merged were 58-60, 61, 62-63, M-N, R, and S, indicated in orange in Table A1. Of these, the only unmarked industry which was consequential to our analysis was M-N, Professional Services. For that reason the Professional Services industry is omitted for the period 1950-72 in several of the tables and figures.

**Table A1: WorldKLEMS Industries and Merges with EUKLEMS Data**

WorldKLEMS Data		EUKLEMS Data	
WorldKLEMS Code	EUKLEMS Code	Industries Merged from WorldKLEMS	
TOT	TOT	TOT	
MARKT	MARKT	MARKT	
AtB	A	AtB	
C	B	C	
D	C	D	
15t16	10-12	15t16	
17t19	13-15	17t19	
20	16-18	20, 21t22	
21t22	19	23	
23t25	20-21	24	
23	22-23	25, 26	
24	24-25	27t28	
25	26-27	30t33	
26	28	29	
27t28	29-30	34t35	
29	31-33	36t37	
30t33	D-E	E	
34t35	F	F	
36t37	G	G	
E	45	50	
F	46	51	
G	47	52	
50	H	60t63	
51			
52			
H	I	H	
I	J	64	
60t63	58-60		
64	61		
JtK	62-63		
J	K	J	
K	L	K	
70	M-N		
71t74	O-U	LtQ	
LtQ	O	L	
L	P	M	
M	Q	N	
N	R-S	O	
O	R		
	S		