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ABSTRACT

By merging KLEMS data sets and aggregating over the ten largest Western European nations (EU-10), we are able to compare and contrast productivity growth up through 2015 starting from 1950 in the U.S. and from 1972 in the EU-10. Data are provided at the aggregate level, as well as for 16 industry groups within the total economy and 11 manufacturing sub-industries. The analysis focuses on outcomes over four time intervals: 1950-72, 1972-95, 1995-2005, and 2005-15. We interpret the EU-10 performance as catching up to the U.S. in stages, with its rapid growth of 1950-72 representing a delayed adoption of the inventions that propelled U.S. productivity growth in the first half of the 20th century, and the next EU-10 stage for 1972-95 as imitating the U.S. outcome for 1950-72. We show that both the pace of aggregate productivity growth during 1972-95 for the EU-10 as well as its industrial composition matched very closely the growth record of the U.S. in the previous 1950-72 time interval.

A striking finding is that for the total economy the “early-to-late” productivity growth slowdown from 1972-95 to 2005-15 in the EU-10 (-1.68 percentage points) was almost identical to the U.S. slowdown from 1950-72 to 2005-15 (-1.67 percentage points). There is a very high EU-U.S. correlation in the magnitude of the early-to-late slowdown across industries. 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 on both sides of the Atlantic.

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1. Introduction

Slowing labor productivity growth for any given income share of labor directly limits the growth rate of real wages and of a nation's standard of living. Each percentage point by which labor productivity growth declines from its previous value translates into a one percentage-point reduction 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 labor productivity, its growth rate in the U.S. has declined from 2.7 percent per year during 1950-72, to 1.9 percent during 1972-2005, to 1.1 percent during 2005-17. In the 15 Western European members of the European Union prior to its 2004 enlargement (the "EU-15"), the same growth measure declined even more sharply from 4.7 percent per year during 1950-72, to 2.0 percent during 1972-2005, to a mere 0.8 percent during 2005-17.[1]

This paper provides a comprehensive examination and comparison of labor productivity growth by industry in the U.S. 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, labor 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 were 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 U.S., our data allow a detailed comparison with the EU. Second, in contrast to recent U.S. research (e.g., Baily-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.[2] For the EU we have merged two data sets that allow our analysis to extend from 1972 to 2015 and to cover ten of the 15 nations of the EU-15, including all the largest nations, hereafter the EU-10.[3]

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[1] The growth rates for the U.S. and EU-15 come from the Conference Board Total Economy Database.

[2] 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.

[3] 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 percent of the GDP of the EU-15 (*Source:* Conference Board Total Economy Database).

There are two important differences in the timing and pace of the productivity growth slowdown in the U.S. and EU-10. The first, already identified above, is that the post-1972 slowdown in the EU was much sharper than in the U.S. The second is that the U.S. enjoyed a temporary productivity 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 1950-72 to 1972-95 to 1995-2005 to 2005-2015, whereas the U.S. experienced a slowdown from 1950-72 to 1972-95, then a marked but temporary growth revival in the 1995-2005 interval, followed by another slowdown after 2005.

Despite these differences, this paper provides a new interpretation that points to similarities between the U.S. 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 U.S. over the entire period from 1950 to 1995. Starting in 1950 at a productivity level only 50 percent of the U.S., the EU caught up to 81 percent by 1972, growing much more rapidly than the U.S. 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 20th century. After 1972 it continued to catch up but at a slower pace, and we show that EU productivity growth in 1972-95 was a mirror image of U.S. growth in the prior 1950-72 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 1972-95 and the U.S. 1950-72 in the industry-by-industry productivity growth rates.

By linking the U.S. experience in 1950-72 to the EU-10 growth pattern of 1972-95, we are able to point to another striking similarity. The productivity growth slowdown from these early periods to the most recent 2005-15 interval was an almost identical -1.68 percentage points for the EU-10 and -1.67 points for the U.S. 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.[4]

Throughout the paper we distinguish between industries producing commodities and those producing services. We show that the post-1972 U.S. productivity growth slowdown occurred entirely within the commodities sector, with no slowdown at all for services, while almost all of the post-1995 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 commodities 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 that commodities dominated the post-1995 U.S. revival,

[4] The "early-to-late" slowdown refers to the change in U.S. productivity growth from 1950-72 to 2005-15 and to the change in EU-10 productivity growth from 1972-95 to 2005-15.

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, dividing labor productivity growth into the contributions of capital deepening, changing labor composition, and MFP. We show that MFP changes dominated the post-1972 U.S. slowdown and post-1995 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 labor 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 U.S. and EU-10, the post-1995 U.S. revival contrasts sharply with the post-1995 EU slowdown. The ratio of the level of EU-10 productivity to that of the U.S. fell from 106 percent in 1995 to 90 percent in 2005. We show that the ranking of industries in their 1995-2005 growth rates was similar in the U.S. and EU-10 but that for most industries European growth was only about half that in the U.S. 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 percent in the U.S. compared to 4.8 percent in the EU-10. Measures of intensity of ICT use that we develop from KLEMS data all show higher values for the U.S. than the EU during this period, and a regression analysis points to a greater response of labor productivity to intensity of ICT use in the U.S. than in the EU-10.

The consensus in previous studies of the post-1995 U.S. productivity growth revival is that this temporary resurgence was caused by the ICT revolution (see, for example, Jorgenson and Stiroh (2000), Oliner and Sichel (2000), and Stiroh (2002)). Industries that produced ICT hardware and software experienced particularly rapid productivity growth during that period, while other industries that were intensive in ICT investment accounted for the rest of the growth revival and relatively non-ICT-intensive industries experienced little or no growth revival. We support this finding for the post-1995 revival but find that the post-2005 slowdown was not symmetric. It was not entirely caused by the disappearance of the productivity-boosting contribution of ICT-intensity in the sense that non-ICT industries experienced a substantial slowdown after 2005 even though they had not enjoyed a revival after 1995.

In the EU data we find a smaller stimulus to productivity growth in ICT-intensive industries after 1995 that is barely enough to offset the decline in growth experienced by the non-ICT industries, leaving the ICT-intensive EU industries with no post-1995 revival at all. After 2005 non-ICT industries experienced a further slowdown, and on top of this the ICT-intensive industries experienced even more of a slowdown, so that by some measures of ICT intensity the ICT-using industries wound up in 2005-15 with lower productivity growth than industries that were not intensive in ICT use. Thus one of the ironies of our overall conclusions is that the EU-10 was very successful in catching up to the U.S. pre-1950 performance in 1950-72 and to the U.S. 1950-72 performance during 1972-95. But the EU-10 utterly failed to catch up to the U.S. revival of 1995-2005, either before or after 2005.

2. The Economy-wide Growth Experience

Before examining data at the level of individual industries, we provide a depiction of labor productivity growth and its major contributing factors for the total economy and several of its main sectors. Figures 1a and 1b compare the rate of labor productivity growth in the U.S. and EU-10 from the KLEMS data. To smooth out sharp changes from year to year, the data are plotted as centered five-year moving averages of annual growth rates. Shown for the U.S. are growth rates for the total economy and what KLEMS calls the "market" economy for 1947-2015, implying that the centered five-year moving averages extend from 1949 to 2013.[5] For the EU-10 the same two series are based on data from 1972 to 2015. To extend the EU-10 data backwards before 1972 for comparison with the U.S., we use real GDP per hour from the Conference Board Total Economy Database, and this backwards extension is only available for the total economy, as shown by the dashed blue line, and not for the market sector.

Turning first to the U.S. growth rates in Figure 1a, we note that the five-year moving averages do not remove all of the cyclical movements. There are strong peaks for the market economy in 1951, 1964, 1977, 1985, and 2001-02, and sharp troughs in 1980 and 2013. There are flatter peaks for the total economy in the same and adjacent years, and a prolonged interval of relatively steady growth at around 3 percent for the entire period between 1955 and 1970. The total economy displays the same sharp troughs in 1980 and 2013 as does the market economy. Stepping back from the cyclical movements and 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 patter are industries that produce commodities, not industries that produce services.

A notable feature of Figure 1a for the U.S. is the sharp divergence between the growth rates of productivity for the total and market economies during 1950-53. This feature of the five-year moving averages reflects strongly negative productivity growth in the non-market sector in annual data for 1947-50, for which the growth rate was an implausible -9.1 percent per year. This peculiar behavior may reflect a mistake in the KLEMS data or perhaps an interval of readjustment and reallocation in the early postwar years. We choose to exclude these years from our subsequent data analysis, making the initial year of the pre-1972 time interval in our subsequent tables begin in 1950 rather than 1947.

[5] Compared to the total economy, the market economy in the KLEMS definition excludes the following industries: real estate, education, health care, and public administration.

The evolution of the centered five-year moving averages for the EU-10 is smoother than for the U.S., with no sharp peaks or 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 U.S. with its late 1990s revival, the EU-10 experience appears to be a continuous slowdown in stages. Productivity growth was greater than 5 percent per annum between 1960 and 1971, then slowed sharply to the range of two to three percent during 1973-96, then slowed further to the range of one to two percent during 1997-2007, and remained below one percent per year after 2007. The difference between the total and nonmarket economy growth paths is generally smaller in the EU-10 than for the U.S., reflecting the fact that productivity growth in the market and nonmarket sectors was not as different in the EU-10 as it was in the U.S.

The trends of average annual productivity growth rates over sub-intervals divided at 1972, 1995, and 2005 are shown in Table 1 for the U.S. and EU-10, and for the total, market, and non-market sectors. As well 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 1972-95 and 2005-15 than in 1950-72 or 1995-2005. The post-1995 revival in the market economy brought its growth rate up to 2.89 percent per year, close to the 3.05 percent per year registered for 1950-72, while the final interval of 2005-15 experienced a growth rate of 0.86 percent, lower than the previous slow period of 1972-95 when market productivity growth was 1.66 percent.

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 post-1995 revival occurred within the CP industries, with no difference in the productivity growth rate of the SP industries when 1950-72 is compared to 1972-95 and only a relatively small SP revival in 1995-2005. This raises questions that we explore subsequently as to whether ICT investment had as much impact in the SP industries after 1995 as in the CP industries. However, the CP and SP industries experienced a similar post-2005 slowdown; when compared to 1995-2005 the CP slowdown was 2.33 percentage points in comparison to the SP slowdown of 1.94 points.

The story is simpler for the EU-10, where for the total economy productivity growth decreased in each period, most sharply between 1950-72 and 1972-95. 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 U.S. For the total economy trend growth in the EU-10 started out at double the rate of the U.S. in the initial 1950-72 interval and gradually decreased until in 2005-15 it was virtually identical. EU-10 growth in the non-market sector was substantially slower than in the U.S. in the last two intervals covering 1995-2005 and 2005-15. The distinction between the CP and SP industries is also more straightforward for the EU-10 than for the U.S. CP productivity growth started out in 1972-95 roughly double that of the SP industries and then slowed down more rapidly, so that by 2005-15 CP growth of 0.95 percent per year was little different from SP growth of 0.64 percent per year. This reinforces our emphasis on the strong contribution of the CP industries as contributors to the overall slowdown between the early and late time intervals in both the U.S. and the EU-10.

The fact that the EU-10 had more rapid productivity growth than the U.S. prior to 1995 but slower growth after 1995 implies that the *level* of EU-10 labor productivity caught up to that of the U.S. prior to 1995 and then fell back after 1995. In the pre-1995 interval the EU-10 more than caught up to the U.S., with the ratio of its productivity level rising from 50 percent in 1950 to 81 percent in 1972 to 106 percent in 1995.[6] Thus, despite suggestions in the literature that the European economy has structural flaws the 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. post-1995 growth revival, particularly the rapid growth the U.S. achieved from 1998 to 2004. The ratio of the EU-10 to the U.S. productivity level declined from 106 percent in 1995 to 90 percent in 2005 and slightly further to 86 percent in 2015.

The shares in total value-added of the market and non-market sectors shown in Table 1 were not constant over time. For the U.S. the non-market share increased from 30 percent of the total in 1973 to 33 percent in 2015, while for the EU-10 that share increased by a greater amount, from 20 percent in 1973 to 31 percent in 2015. Since the productivity growth rate was slower in the non-market sector, these shifts in share should have contributed to slower overall productivity growth. For the U.S. the shift in share was too small to make a difference, but for the EU-10 a hypothetical calculation fixing the non-market share at its 1972 value yields a hypothetical total economy growth rate slightly faster than the actual rate, since less weight is put on the slow-growing non-market sector. The hypothetical EU-10 growth rate is faster than the actual rate by 0.08 points in 1972-95, 0.12 points in 1995-2005, and 0.06 points in 2005-2015. However, the slowdown from the first to the last period was slightly slower with the hypothetical fixed-share series, a trivial difference of 0.02 points.

An interesting feature of Table 1 is the close similarity of the U.S. growth rates in 1950-72 with the EU-10 growth rates in 1972-95. The rapid EU growth of 1950-72 can be interpreted as "catch-up"[7] growth after the economic dislocations of the two world wars and the interwar period, when the U.S. leaped ahead of the EU in its level of labor productivity. In 1950 the level of EU-10 labor productivity was only 50 percent 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

[6] The ratio of EU-10 to U.S. labor 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.

[7] 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."

early twentieth century that had become common in the U.S. before World War II, and so after 1972 EU-10 productivity growth slowed down to a rate very similar to that of the U.S. in the early postwar years, 1950-72. When we interpret 1950-72 for the U.S. as being comparable to 1972-95 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 labor productivity growth from these comparable periods to 2005-15 was exactly the same, -1.67 points for the U.S. 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 U.S. (-2.13 points). The slowdown in the SP industries in the U.S. was slightly greater in the U.S. than in Europe (-1.29 vs. -1.05 points). This measure of slowdown was quite different in the non-market sector, reflecting the unusually slow growth for the non-market sector in the U.S. in the early postwar years.

The standard sources-of-growth decomposition divides growth in labor productivity among the contributions of multi-factor productivity (MFP), capital deepening, and changes in labor composition. Figure 2 provides for the same time intervals as Table 1 a graphical depiction of these three respective contributions to total economy labor productivity growth as green, purple, and gold slices in the horizontal bars, the total width of which represents labor productivity growth. Here we notice interesting differences between the U.S. and EU-10. For the U.S. the contribution of capital deepening was virtually the same in the first three periods – 1.34, 1.11, and 1.25 respectively, indicating that virtually all of the post-1972 productivity growth slowdown and post-1995 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. The contribution of labor composition was virtually the same in all four intervals and so adds nothing to an explanation of the transitions down after 1972, up after 1995, and down after 2005.

For the EU-10 the relative roles of MFP and capital deepening were different than in the U.S. In each of the transitions there was a slowdown in the growth rate of labor productivity that is explained by a slowdown in both the contribution of MFP and of capital deepening.[8] 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 labor composition contribution was small and notably reversed sign toward a higher contribution in 1995-2005 than in the second and fourth intervals.

Figure 3 shows the division of the contributions in explaining each of the transitions of Figure 2. Each horizontal bar sums to 100 percent, and the same colors as in Figure 2 indicate the share of the MFP, capital deepening, and labor composition contributions to the transitions between time intervals. For the U.S. the large green segments show the dominant role of MFP

[8] Figures 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

in causing the down and up of labor productivity growth in the post-1972 slowdown and post-1995 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 post-1972 slowdown, while the roughly equal green and purple areas show joint responsibility in the post-1995 and post-2005 slowdowns. Note that the sum of the green and purple EU bars for the post-1995 transition sums to more than 100 percent, because the contribution of labor composition goes in the opposite direction (up) from the direction of the MFP and capital deepening contributions (down).

The green and purple shares in Figure 3 help to focus our attention on the underlying causes of the changes in labor productivity growth over these intervals. A predominance of green indicates that productivity growth changes are mainly caused by changes in MFP growth, indicating a greater role of innovation. A predominance of purple indicates that productivity growth changes are mainly caused by changes in investment that lead to a different pace of capital deepening. Viewed in this way, the U.S. post-1972 slowdown and post-1995 revival were largely a story of the shifting role of innovation, while the post-1995 slowdown combined the impact of innovation with a depressed contribution of investment. For the EU-10 innovation dominated in the first post-1972 slowdown, while innovation and investment shared responsibility for the further post-1995 and post-2005 growth slowdowns. Subsequently we will examine the role of a particular type of investment, that in ICT, as a cause of the post-1995 U.S. revival and post-2005 U.S. slowdown. We shall also investigate several measures of the intensity of ICT investment in the EU-10 in an attempt to determine why there was no post-1995 European productivity growth revival as there was in the U.S.

3. Industrial Sector Behavior for the United States

In contrast to the EU-10, which experienced a steady slowdown in labor productivity growth from one time interval to the next, the U.S. alternated between a post-1972 slowdown, a post-1995 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 U.S.

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 post-1995 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 2a presents labor productivity growth rates for the U.S. 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, nonmarket, commodities, and services – are shown in bold and are identical to the same growth rates presented above in Table 1.

In the initial 1950-72 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 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 1950-72 negative rate of public sector productivity growth may be spurious in the underlying KLEMS data for this early time interval.

In the next interval – 1972-95 – labor productivity growth declined by half in the total economy (from 2.54 to 1.25 percent) and by almost half in the market sector (from 3.05 to 1.66 percent). Which industries accounted for the slowdown? As shown in Table 2a 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 table (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 nonmarket 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.

Table 2b performs the calculation of change from one period to the next for the same industries as appear in Table 2a. In the post-1972 transition the largest slowdowns were for mining, utilities, and construction, while the biggest speedup was for finance and insurance and, in the non-market sector, public administration.

Productivity growth revived from 1972-95 to 1995-2005 in the total economy from 1.25 to 2.17 percent and in the market sector from 1.66 to 2.89 percent. 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 percent, while the revival for the SP industries was only from 2.20 to 2.84 percent. 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 post-1972 slowdown and post-1995 revival has received relatively little comment in the literature.

Six industries experienced an increase in productivity growth of more than one percentage point after 1995, and four of these achieved a growth rate faster than in the initial 1950-72 period (agriculture, manufacturing, wholesale/retail, and professional/administrative). As shown in Table 2b, the sharpest changes in the post-1995 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 percent 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, from 2.17 percent to 0.87 percent in the total economy and from 2.89 to 0.86 percent in the market sector. The decline of more than two percentage points in the market sector was greater than the previous slowdown from 1950-72 to 1972-95. Within the market sector the CP and SP industries experienced a slowdown of roughly the same size as shown in Table 2b, of -2.33 and -1.94 percent respectively. Six industries experienced a decline of more than one percentage point *and* recorded lower productivity growth than in the previous slowdown period of 1972-95. In descending order of the extent of the slowdown, as shown in Table 2b, 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 1972-95. Utilities experienced a slowdown of -1.23 points but grew faster than in 1972-95. Mining was the notable outlier and went in the opposite direction, experiencing a sharp growth revival of 4.85 percent. 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.

A correlation analysis can reveal patterns across the time intervals both in the growth rates depicted in Table 2a, and in the changes between time intervals shown in Table 2b. Across the columns in Table 2a, there is a relatively high correlation coefficient of 0.79 across market industries between the productivity growth rates of 1972-95 and 1995-2005. This means that the industries that grew the fastest between 1972 and 1995 also grew the fastest between 1995 and 2005. This relationship is illustrated in the scatter plot of Figure 4a, which includes a 45 degree line indicating equal growth in the 1972-95 and 1995-2005 intervals, and a regression line positioned above the 45 degree line describing the relationship between industry growth rates in the two intervals. The regression constant is 1.11 percentage points and the slope coefficient is a highly significant 0.92. The three dots in positive territory that lie above the regression line illustrate the strong contribution to the post-1995 growth revival of agriculture, manufacturing, and wholesale/retail.

Perhaps most interesting is the strong negative correlation coefficient of -0.69 across the market industries between the post-1995 revival and the post-2005 slowdown. As illustrated in the scatter plot of Figure 4b, those industries that experienced the largest revivals after 1995 also experienced the greatest slowdowns after 2005, particularly agriculture, manufacturing, utilities, wholesale/retail, and hotels/restaurants.[9] The regression line in Figure 4b 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 post-1995 revival. Subsequently we study whether that technological change can be linked to the relatively intensive use of ICT equipment in the industries that experienced revivals followed by slowdowns.

Another way to highlight those industries that were most important in the post-1972, post-1995, and post-2005 transitions is to calculate their contributions to the total change in productivity growth over those transitions. This is done by multiplying the change in productivity growth from one time interval to the next by the share in value-added of the particular industry. The results are displayed graphically in Figures 5a through 5d and focus on the market sector, omitting the four industries of the nonmarket sector to simplify the discussion.

We learned previously that the post-1972 U.S. growth slowdown was quite pervasive, with eight of 12 market industries experiencing slower growth, and that the slowdown was concentrated in the CP industries listed at the top of Table 2a. Figure 5a displays the contributions to the post-1972 slowdown, where the overall slowdown in the market sector was -1.39 percent, as shown by the long bar at the bottom. Looking at the bars moving up from the bottom, we see that the largest contributions to that slowdown in descending order of size were made by the manufacturing, construction, utilities, and agriculture, all of which are CP industries.

Figure 5b displays the same decomposition of contributions to the post-1995 U.S. productivity growth revival, which as shown by the top bar for the market economy was 1.24 percentage points, the difference between the 1995-2005 growth rate of 2.89 percent and the 1972-95 growth rate of 1.66 percent. Once again the leading contribution was made by manufacturing, but thereafter the contributing industries were all in the SP sector rather than the CP sector, namely professional/administrative, wholesale/retail, finance/insurance, and hotels/restaurants. This seems paradoxical given the relatively small overall revival registered by the SP sector and reflects the relatively large weight of these particular SP industries in total value added.

[9] A similar graph illustrating this negative correlation appears in Baily-Montalbano (2016, Figure 9).

The final post-2005 slowdown in Figure 5c was larger than the initial post-1972 slowdown and amounted to -2.03 percentage points, as shown by the long red bar at the bottom. Once again manufacturing made the largest contribution, but then the next four largest contributions were made by SP industries – in descending order wholesale/retail, finance/insurance, transportation services, and hotels/restaurants. The appearance of the same industries as the major contributors to the post-2005 slowdown as to the post-1995 revival is consistent with the strong negative correlation across all market-sector industries that was plotted above in Figure 4b.

Finally it is interesting to skip over the post-1972 and post-1995 transitions and to examine the change in productivity growth by industry between the first 1947-72 interval and the last 2005-15 interval. Figure 5d displays as the bottom red bar the total change in the market sector of -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 20th century that boosted productivity growth in the CP industries during 1950-72 but faded out in importance after 1972.[10]

4. 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 3a displays their growth rates of labor productivity in the same format as Table 2a. Productivity growth was robust in the initial 1950-72 interval, with seven of the eleven sub-industries displaying growth rates of 3.5 percent or above. The metals sub-industry was an outlier, with growth of only 1.10 percent, and indeed experienced relatively slow growth in all four of the time intervals.

Changes across the transitions are shown in Table 3b. In the post-1972 transition productivity growth declined by 0.98 percent for total manufacturing and by more than two percent in five of the eleven sub-industries, with particularly sharp declines of more than five percent 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.[11] The

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[10] Baily-Montalbano (2016) also highlight the role of agriculture, manufacturing, and retail/wholesale in the post-1995 productivity growth revival and post-2005 slowdown.

[11] *Source:* Spot crude oil price, West Texas Intermediate, from FRED.

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 percent per year, reflecting the growing importance in this sector of the manufacture of ICT equipment.

As previously displayed in Table 2a, the manufacturing sector enjoyed a sharp post-1995 revival in productivity growth from 2.43 to 5.53 percent per year, or an increase of 3.10 percent. This increase as shown in Table 3b was consistent across sub-industries, as six of the 11 sub-industries experienced a productivity growth revival of two percent or more, led by the enormous 8.58 percentage point revival for petroleum, and revivals of 3.5 percent or more for electrical machinery (which reached a stunning growth rate of 17.5 percent), machinery n.e.c., and transportation machinery. In four of these six industries with a revival of two percent or more, productivity growth in 1995-2005 was faster than in the initial interval of 1950-72, with an enormous margin for electrical machinery, while transportation equipment registered double the productivity growth in 1995-2005 as in 1950-72. 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 percent, for a slowdown of 3.63 points. Six of the eleven sub-industries experienced growth slowdowns of two percent or more, led by the enormous declines of petroleum (-12 percent) and electrical machinery (-10.5 percent)[12]. Seven industries display growth rates in 2005-15 that are below their growth rates in the initial slowdown period of 1972-95. Not a single manufacturing sub-industry recorded faster growth in 2005-15 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 percent that was still relatively high. Next comes the majority of industries (seven of 11) that experienced a zig-zag from high growth in 1947-72 to lower growth in 1972-95, 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 post-1995 revival at all; textiles and apparel remained strong throughout until 2005 with no 1972-95 slowdown; and metals registered slow growth throughout interrupted by a slight improvement in 1995-2005.

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

The discussion of the industrial breakdown of labor productivity growth for the EU-10 can be briefer than in the U.S., both because there are no data for the pre-1972 interval and also

[12] 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 3b.

because the pattern of change for the EU-10 is a steady decline rather than the alternation of slowdown-revival-slowdown that we have observed for the U.S. Table 4a displays EU-10 productivity growth for the same industries and same format as Table 2a, but here we have three periods rather than four – 1972-95, 1995-2005, and 2005-2015. 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 1972-95 interval five of the 12 industrial sectors in the market sector exhibited growth of more than 2.5 percent, 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 1972-95, 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 U.S., the transition was from a much higher growth rate (5.46 to 4.04 for the U.S., 2.11 to 3.84 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 2a and 4a, we see that the EU-10 had faster productivity growth during 1972-95 than the U.S. in eight of the 12 industries, including all five of the CP industries. The pattern was reversed for the 1995-2005 interval, with the U.S. 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 U.S. in 1995-2005 exceled 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 U.S. and EU-10, with small positive or negative numbers except for growth slightly above one percent in EU-10 public administration[13].

One of the most notable differences between the EU-10 and the U.S. is the failure of the EU to mimic the post-1995 growth revival enjoyed by the U.S. Yet the best-performing EU-10 industries during 1995-2005 were in most cases the same as in the U.S., sufficiently to create a correlation coefficient across industries of 0.71 between the 1995-2005 productivity growth rates in the EU vs. U.S. As we shall see again below in Figure 9b, 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,

[13] 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 U.S. Among these papers are Uppenberg *et al*. (2010), Timmer *et al*. (2011), Inklaar *et al.* (2005), Van Mark *et al*. (2008), and Inklaar *et al.* (2007).

and professional/administrative. There is only a 0.08 correlation across industries between EU 1995-2005 growth and the *difference* by industry between U.S. and EU growth.

After 2005 EU-10 productivity growth slowed to 0.63 percent per year in the total economy, little different than the sluggish 0.87 percent pace registered by the U.S. The post-1995 slowdown in the U.S. was greater than in the EU-10, because the U.S. 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 percent 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 4b compares EU-10 productivity growth by industry for 2005-15 with that for 1972-95. Four of the 12 industries in the market sector experienced slowdowns of more than 3.0 percent, and three of these 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). All the industries in the non-market sector experienced slower productivity growth, although for most the declines were small because growth in the initial 1972-95 interval was relatively slow. In fact there is a general tendency for the industries that grew the fastest in the initial 1972-95 interval to have the largest growth slowdowns to 2005-15. The correlation coefficient between 1972-95 growth rates and the slowdown shown for the EU-10 market sector in table 4b 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 1972-95 to 2005-15 as the U.S. experienced from the earlier 1950-72 period to 2005-15 (-1.67 points). To further explore this close similarity between the two overall slowdowns, Table 4b adds an additional column that shows the change for each industry in U.S. productivity growth from 1950-72 to 2005-15. 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 U.S. had no slowdown at all in mining, one of the worst-performing EU sectors, and the U.S. experienced an overall rise in productivity growth compared to a EU slowdown in finance/insurance and arts/entertainment.[14]

How closely related are the EU-10 vs. U.S. slowdowns shown in Table 4b? Leaving aside the professional/administrative industry, for which no U.S. data are available in the earlier interval, the correlation coefficient in the market sector between the EU and U.S. slowdowns is

[14] The U.S. cell for professional/administrative is empty because data for that industry are missing for part of the 1950-72 interval.

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 U.S. but not in the EU-10. Overall, 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 4b.

The close correlation between the EU and U.S. slowdowns extends further to the close 0.79 correlation across industries in the productivity growth rate achieved during 1950-72 for the U.S. with that recorded for the EU-10 during 1972-95. 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. We note further that for the EU-10 four of the five fastest-growing industries in 1972-95 were producing commodities, and for the U.S. the same four CP industries were among the six fastest growing industries. In both the EU-10 and in the U.S. the construction industry was the only CP industry that failed to achieve productivity growth in the top performing group.

Just as Figure 5d displayed the contribution by industry for the U.S. between the early 1950-72 and late 2005-15 periods to the slowdown in market sector productivity growth, so Figure 6 displays the same contributions for the EU-10 between its early 1972-95 interval and 2005-15. With the exception of professional/administrative, for which there are no early data for the U.S., the list of the six most important industries contributing to the slowdown is the same for the U.S. and EU-10. And the contributions are in roughly the same order, as evidenced by the remarkably high 0.85 correlation across industries in the contributions displayed in Figure 5d compared with Figure 6. This supports our theme that the overall 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 U.S. and in the EU-10. The most important difference is that wholesale/retail was in second rank for the U.S. with its contribution of –0.59, whereas that industry was in seventh place for the EU-10 with a much smaller contribution of -0.10.

6. 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 5a, while the slowdown from the first to last period is exhibited in Table 5b. In the initial 1972-95 interval productivity growth was robust across manufacturing, with eight of the 11 sub-industries reporting growth of more than 2.5 percent. Only petroleum fell short, with growth below 1.0 percent, which is interesting because U.S. petroleum suffered a severe growth slowdown after 1972. This similarity of slow productivity growth in the U.S. and EU-10 petroleum refining industries may reflect the influence of the oil price shocks of 1973-75 and 1979-81.

Growth in total manufacturing declined modestly after 1995 from 3.46 percent in 1972-95 to 2.87 percent 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 a growth slowdown of more than 1.0 percent. 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, as the correlation coefficient across industries of growth rates for 1972-95 versus 1995-2005 is a high 0.84.

There was a larger slowdown after 2005, from 2.87 to 1.84 percent 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 2005-15. 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.

Table 5b displays the slowdown from the first (1972-95) to last period and provides a comparison with the U.S. slowdown from its first (1950-72) to last period. Once again there are important similarities but also a major difference. The slowdowns for total manufacturing is similar, -1.62 for the EU-10 and -1.51 for the U.S., and these magnitudes are quite similar to the -1.67 and -1.68 slowdowns for the total economy over the same time comparison. The pattern is somewhat different, as several of the industries experience substantially greater slowdowns in the U.S. than in the EU-10. This is particularly evident for petroleum. Also experiencing substantially greater slowdowns in the U.S. are food, textiles, machinery n.e.c., and other manufacturing. Partly offsetting these greater slowdowns are the totally different behavior of electrical machinery, which (despite a big slowdown from 1995-05 to 2005-15) grew substantially faster in the final period than before 1972 in the U.S., whereas growth for the EU-10 electrical machinery industry in 2005-15 was slower than in 1972-95. The correlation across industries for the slowdowns shown in table 5b is 0.43 for the 11 industries but jumps to 0.73 when the electrical machinery industry is excluded.

7. Was Slowing Innovation or Flagging Investment Responsible for the Slowdown?

Above in Figures 2 and 3 we discussed charts showing the decomposition of labor productivity growth in our four intervals in both the U.S. and EU-10 among the respective contributions of MFP growth, capital deepening, and changes in labor composition. We noted that in both the U.S. and EU-10 the contributions to the post-1972 slowdown were dominated by MFP. The post-1995 revival for the U.S. was also dominated by the contribution of MFP, while responsibility for the post-1995 slowdown for the EU-10 was split roughly evenly between MFP and capital deepening. For both the U.S. and EU-10 the post-2005 slowdown was also roughly evenly split between MFP and capital deepening.

Now we look at these contributions by industry and focus on the early-to-late slowdowns that were previously illustrated for labor productivity growth in Figures 5d and Figure 6. Figure 7a shows contributions by industry for the market economy to the U.S. slowdown between 1950-72 and 2005-15. Green segments measure the contribution of MFP, purple segments the contribution of capital deepening, and gold segments the contribution of changes in labor 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. The green bar for the total economy representing the -0.85 point negative MFP 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 contribution of capital deepening almost exactly offsets the positive mining MFP contribution, resulting in a change in labor productivity growth of almost exactly zero (mining productivity growth in Table 2a was 2.97 percent during 1950-72 and 2.98 percent during 2005-15). 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 percent. 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 labor 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.

Figure 7b displays in the same format the contributions to the EU-10 productivity slowdown from 1972-95 to 2005-15. 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 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 labor 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 U.S., but here the positive and negative numbers are less than half as large.

How similar are the U.S. 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 now examine the same comparison for the 11 sub-industries within manufacturing. As shown in Figure 8a for the U.S. all sub-industries except for electrical machinery and transportation equipment had negative MFP contributions. 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 labor productivity growth slowdown. The bottom seven listed industries all have negative MFP contributions of greater than -3.0 percentage points, and the contribution of petroleum is an enormous -10.47 points. Capital deepening contributions are generally small and range from 1.69 for chemicals to -1.34 for machinery n.e.c. Thus manufacturing is the sector of the economy in which the case for a technological explanation of the productivity growth slowdown is the strongest.

The same display for the EU-10 is presented in Figure 8b. Here capital deepening plays a larger role in explaining the slowdown, as compared to a slight offsetting role in the U.S. 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 labor 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 in petroleum and -1.89 in electrical machinery. It is notable that electrical machinery performed so poorly in Europe, in contrast to the U.S. 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 U.S. 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 Figures 6a and 6b 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 U.S.

How closely related between the EU and U.S. are the industries making the largest contributions to productivity growth and the growth slowdown? The first row and first column of Table 6 reports for the total economy on a regression of productivity growth by industry in the EU-10 during 1972-95 on productivity growth by industry in the U.S. during the earlier time interval 1950-72. The constant is a significant 0.90 and the coefficient is a highly significant 0.49. The data points and the regression line are plotted in Figure 9a, 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 1972-95 EU-10 performance superior to that in the U.S. during 1950-72 – namely, agriculture, manufacturing, mining, and transportation services.

The second column of the top row in Table 6 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 U.S. enjoyed a productivity growth revival after 1995 but the EU did not, the second row of Table 6 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 U.S. Figure 9b 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 U.S..

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 1972-95 to 2005-15) and the industries in the U.S. in its early-to-late slowdown (1950-72 to 2005-15). 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 Figure 10, 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 U.S. -- agriculture, manufacturing, utilities, transportation services, education, and health.

These results indicate that, at least for the total economy, if in 1972 you had known the rate of productivity growth by industry achieved in 1950-72 for the U.S., you would have been able to do a quite a good job of predicting in advance productivity growth by industry in the EU-10 in the subsequent 1972-95 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. 1950-72 growth rates and those in the EU-10 for 1972-95. 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.

8. **The Impact of the ICT Revolution in the United States and Europe**

Literature Review

The previous literature has attributed much of the post-1995 U.S. acceleration in labor productivity to the ICT revolution, marked by the 1995 arrival of the first web browsers, the founding of new internet firms like Amazon (1994) and Google (1998), together with a massive investment by U.S. business firms in computer hardware and software. Jorgensen *et al.* (2005) emphasize the importance of investments in ICT equipment in driving up productivity growth in the late 1990s, while Corrado *et al.* (2007) likewise discuss the significance of ICT in sustaining that growth through 2004. Stiroh (2002) divides industries into "ICT-producing," "ICT-intensive" and "non-ICT-intensive" industries, finding that almost all the post-1995 growth in productivity can be attributed to ICT-intensive industries, even after controlling for rapid growth in ICT-producing industries.

Despite the broad consensus on the impact of ICT on the acceleration of U.S. productivity growth in the late 1990s, the subsequent post-2005 decline in productivity growth raises questions whether the growth stimulus of ICT investment was temporary rather than permanent. Did the ICT Revolution have a sustained positive impact on productivity growth, or was it a one-time shock? In Fernald's (2015) interpretation the ICT revolution had a temporary "level effect" that resulted in a marked but short-lived period of additional productivity growth that ran its course after about a decade. Extending Stiroh's result, Fernald suggests that both the rise and the fall of labor productivity growth resulted from a temporary boost to productivity growth for ICT-producing and ICT-using industries. Cette *et al.* (2016) likewise claim that the ICT revolution had run its course by 2004. Byrne *et al*. (2016) maintain that while ICT-innovations continued, they were not potent enough to prevent a broad post-2004 slowdown in productivity growth. They also suggest that the subsequent wave of innovation associated with smartphones and social networks has enhanced consumer surplus without appreciably raising business sector productivity.

Some literature calls into question the extent of the ICT impact on the late 1990's U.S. productivity growth revival. Acemoglu *et al*. (2014) in a study of U.S. manufacturing show little difference in the degree of growth resurgence between ICT-using and non-ICT-using industries during the late 1990s and early 2000s. While they do find a positive impact on labor productivity for manufacturing industries that utilize high-tech equipment in this period, they cast doubt on the proposition found in much of the literature that ICT-intensity can explain the entire post-1995 revival.

Another puzzle is how the ICT revolution did or did not foster growth in European economies over the same time period. Although European industries had access to the same

ICT technology as the U.S., sometimes even having similar shares of ICT capital in total investment spending, Europe experienced a productivity growth slowdown after 1995 in contrast to the revival that the U.S. enjoyed in the same period. Castellani *et al*. (2016) find that European countries performed worse at both investing in research and development and in transforming that R&D expenditure into a significant productivity growth response. Moreover, these authors contend that while the U.S. shifted its economy to "high-tech" sectors, much of the European economy remained in "medium-tech" and "low-tech" sectors, where capital deepening is the main channel driving productivity growth.

A related theme that emerges from the literature is the difference in the structure of European markets compared to the U.S. Van Ark *et al*. (2008) survey a broad variety of causes, including lower TFP growth and the lower importance of ICT-producing industries in Europe. They end up attributing the absence of a post-1995 productivity growth revival in Europe to the slower emergence of a knowledge economy in Europe, particularly in the services sector, and argue that particular labor market structures and regulatory laws may have played a role in dampening productivity growth. Timmer *et al*. (2011) suggest that the significant decline in European labor force participation and hours worked per person between 1973 and 1995 may have meant that, when the ICT revolution finally came, European industries may not have been ready to reap the benefits of new technologies. Bloom *et al.* (2012) show that US-owned multinational companies that had firms operating in Europe were able to reap the benefits of the ICT revolution while European firms were not, suggesting that differences in management structure between the two regions may have helped drive the Transatlantic productivity gap.

Some authors argued that Europe simply needed to play catch up to the U.S again, as it had done in the early postwar years. For example, Inklaar *et al.* (2007) argue that the main differences between U.S. and EU growth were due to a shortfall in European services sector MFP, and that over the next few years we would see increased ICT investment and a subsequent growth revival in the European economy. The data presented above on the post-2005 EU-10 growth experience show that such a growth revival did not occur. In fact, Dabla-Norris *et al.* (2015) argue that while the services sector drove the gap between U.S. and European productivity growth, the time to tap into the full potential of ICT may have already passed. Cette et al (2016) argue that the U.S. established a technological frontier to which Europe, particularly Southern European countries like Italy and Spain, could catch up to. This explanation fails to explain the lack of an ICT-driven growth revival in EU-10 countries outside of Southern Europe.

Several issues that arise in this literature review can be tested with our KLEMS data. Several alternative indicators of ICT-intensity are available and can be tested for the extent that they explain the post-1995 U.S. revival, the post-2005 U.S. slowdown, and the lack of a revival in the EU-10. The theme that Europe failed to respond to the ICT revolution because of a lesser importance of high-tech and greater importance of low-tech industries can be tested by applying U.S. industrial share weights to EU-10 industry-by-industry productivity growth data. Another theme, that the EU has lagged particularly in the services sector can be tested by examining the role of ICT investment separately in the commodities and services sectors in both the U.S. and EU.

Before turning to ICT's role in the speedup and slowdown of productivity growth, we first examine claim that productivity growth in the EU was held back because its industry mix gave a smaller role to hi-tech industries and a smaller role to low-tech industries. This suggestion can be tested by calculating an alternative aggregate EU productivity growth rate when the U.S. industry mix is combined with EU industry growth rates. We multiply each European industry's labor productivity growth rate by the U.S. value-added share of that industry for each year from 1972 through 2015, and then sum up the industry terms to calculate a hypothetical counterfactual aggregate for EU labor productivity growth. We find that, were the EU-10 to have shared the same industry composition as the United States, total economy productivity growth would have been 1.80 percent for 1972-95, 1.26 for 1995-05, and 0.71 for 2005-15. Compared with the actual growth rates of 2.31, 1.26, and 0.63 for the same time periods, we see that the U.S. industry mix substantially *lowers* EU productivity growth in the first period, makes no difference in the second period, and slightly raises growth in the third period. The big change in the 1972-95 period occurs because the US had a substantially lower share of commodities production during that interval, and since EU commodity growth was almost double growth in the services sector (Table 4a), imposing U.S. share weights reduces counterfactual 1972-95 growth. The counterfactual early-to-late slowdown for the EU is reduced from -1.68 percentage points in the actual data to -1.09 points in the counterfactual experiement.

Creating an Indicator of ICT Intensity

Several alternative ICT-intensity variables are available in the KLEMS data for both the U.S. and EU-10 and for all 27 of the industries that have been featured in our preceding analysis, including the 16 industries into which the total economy is divided, as well as the 11 sub-industries within manufacturing. The first of these indicators is the "ICT Share Dummy," which is formulated in the same way as in Stiroh (2002). We first compute the average ICT share of capital for the 1991-1995 period, where the ICT share of capital is the annual nominal expenditure on computing equipment, communications equipment and computer software and databases, all divided by the total annual expenditure on capital. We then set the "ICT Share Dummy" for a given industry equal to unity if that industry's ICT share is above the median of all industries. In the discussion below we refer to this variable as the "Share Dummy."

The next two dummy variables are computed similarly as 0,1 dummies depending on whether an industry's indicator is above or below the median of all industries. The first of these is the "ICT Nominal Rate of Change Dummy," or "RoC Dummy," which is equal to unity if an industry's nominal rate of change of expenditure on ICT capital was greater than the median for 1991-1995, and is zero otherwise. The use of the 1991-1995 period for the first two indicators prevents endogeneity concerns in studying the causative role of ICT in explaining post-1995 productivity growth behavior.

The third KLEMS ICT variable is the "Contribution Dummy," which is equal to unity if the 1999-2005 contribution of ICT-capital to real value-added growth was greater than the median and zero otherwise. The use of 1999-2005 rather than 1991-95 results from the lack of data availability for the contribution variable prior to 1999 in the KLEMS data releases on which we have relied.

The fourth and final ICT variable is the "Fernald Dummy," adapted from Table A1 in the appendix of Fernald (2015). Although Fernald uses a 60-industry dataset from the U.S. Bureau of Labor Statistics in his analysis, we are able to create correspondences between his industries and ours, allowing us to define particular KLEMS industries as "ICT-intensive." More details on the industry matches are provided in the Data Appendix.

All four of these indicators provide alternative measures of the concept of "ICT intensity." In addition, following the previous literature we single out two industries, "Electrical Machinery" and "Information & Communications" as ICT-producing in order to distinguish between ICT production and ICT use. Note that all of our indicators except for the Fernald dummy can be separately calculated for the U.S. and EU. Thus our KLEMS-based indicators allow us to study the relationship of EU-10 productivity growth to EU-10 ICT-intensity by industry, whereas the EU results for the Fernald dummy refer to the response of EU-10 productivity data to the ICT-intensity of industries within the U.S.[15]

Before proceeding with the regressions, Table 7 shows the actual values of the ICT variables for the total economy, market, commodities and services sectors in the U.S. and the EU-10. Across the board, we see that U.S. has higher values of the ICT indicators than the EU-10. The nominal rate of change of investment in ICT capital is consistently almost twice as high for the U.S. as for the EU-10. While this can in part be explained by Europe's lower rates of investment, as evidenced by the larger role a decline of capital deepening played in Europe's pre-2005 slowdowns than the U.S., Europe's ICT share still lags behind those of the U.S. Although the commodities aggregates have comparable ICT investment shares, the services aggregate has a far larger share in the U.S. Appendix table A1 shows the actual and dummy ICT values for the U.S. and EU-10 at an industry level, and again reveals that the actual variables are consistently lower in the EU-10. Hence, part of the EU-10's lack of response to the ICT revolution can be attributed to lower investment in ICT capital.

Fixed Effects Regression Framework and Results for the U.S.

Each of our regressions utilizes the same basic framework, regardless of the industries included or the dummy variable used. The equation we use is:

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[15] The only other difference between the U.S. and the EU-10 is that while the wholesale and retail industries are able to be treated separately in the U.S., they are combined in the EU-10 due to inconsistencies in the availability of data across individual countries.

$$LP_{it} = \sum_{i\ in\ industry} \alpha^i[1 = industry]_i + \beta^1 Mid_{it} + \beta^2 Late_{it} + \beta^3 Mid * ICT_{it} + \beta^4 Late * ICT_{it} + \beta^5 Mid * ICTProd_{it} + \beta^6 Late * ICTProd_{it}$$

The dependent variable is the five-year centered moving average labor productivity growth rate for industry i at time t. α^i is a fixed-effects dummy for industry i, which represents its average labor productivity growth from the beginning of the regression in 1979 until 1995. The "Mid" variable is a dummy equal to unity after 1995, and the "Late" variable is a dummy equal to unity after 2005; the coefficient β^1 on the former term represents the change in labor productivity from 1979-1995 to 1995-2005 for non-ICT-intensive industries, while the coefficient β^2 on the latter term is the change in labor productivity from 1995-2005 to 2005-2015 for non-ICT-intensive industries. ICT*Mid is an interaction between the ICT variable and the Mid variable, its coefficient β^3 giving the difference in the acceleration of labor productivity growth for ICT-using industries post-1995. In the same way, the ICT*Late coefficient β^4 gives the difference in the acceleration of labor productivity growth for ICT-using industries in the post-2005 transition. Finally, β^5 and β^6 give additional post-1995 and post-2005 effects for the ICT-producing industries, Electrical Machinery and Information & Communication. The use of the dummy variable for ICT intensity for each indicator, instead of the ordinal magnitude of each indicator, allows for comparability across indicators in the effects of ICT intensity on productivity growth.

Because of the suggestion in the literature that the EU lags the U.S. more in the production of services than of commodities, after presenting baseline results, we also provide regressions separately for 15 commodities industries and 12 services industries, including the nonmarket services industries (real estate, public administration, health, and education).

Table 8 shows baseline results for the 27 industries pooled together for the U.S. Each of the four panels arrayed across the columns represents a different ICT variable: the Share Dummy the RoC Dummy, the Contribution Dummy, and the Fernald Dummy. The bottom section of each panel displays a set of overall effects, which compute the average labor productivity estimates for ICT vs non-ICT industries across each time interval: 1979-1995, 1995-2005, and 2005-2015. The base period values for each industry are calculated as the weighted average of the fixed effects constants for the ICT and non-ICT industries. To conserve space the individual fixed-effect constants for the 27 industries are not listed separately.

The low magnitudes and lack of significance on all the "Mid" variables reflect the fact that non-ICT-intensive industries had little significant growth additional growth after 1995 compared to the growth rate they registered in 1979-95. The ICT*Mid interactive terms in all the panels show that there was a significant, positive revival in the post-1995 transition for ICT-using industries, estimated between 0.72 and 1.19 percentage points. This suggests that the post-1995 revival of aggregate productivity growth mainly occurred in ICT-using industries. The high magnitudes of the ICTProd*Mid and ICTProd*Late coefficients reveal that there was a sharp speedup and slowdown in ICT-producing industries, driven by electrical machinery.

Similarly, the results are consistent in showing a major slowdown post-2005 for all industries, estimated at between -1.04 and -1.75 percentage points. The temporary nature of the ICT-use effect can be seen in the "overall effects" in the bottom section of the table, where ICT-using industries in 2005-2015 always return to levels of productivity growth near or lower than their pre-1995 growth rates. However, the results for the four indicators diverge in regards to the ICT*Late term. The overall effects of the three KLEMS variables show that, on average, ICT-using industries began at lower productivity growth rates pre-1995 but ended up at higher growth rates post-2005 than non-ICT-intensive industries. The baseline conclusion from the KLEMS results is that while there was an economy-wide slowdown in productivity growth post-2005, that slowdown was not as dramatic for ICT-using industries. While these industries experienced a slowdown, they ended up closer to their pre-1995 growth rates, while non-ICT using industries plummeted further down to lower growth rates than pre-1995.

The Fernald Dummy tells a different story, suggesting that ICT-using industries had a significant post-2005 slowdown (-1.31 percentage points) that was larger than non-ICT-intensive industries and also greater in magnitude than the amount by which they initially sped up after 1995. The overall effects grid for the Fernald indicator shows that ICT-using industries started at a higher rate of productivity growth than non-ICT-intensive industries, but ended at a level only slightly greater. The Fernald data also makes a case for interpreting ICT investment as a temporary shock, with a fall in productivity growth post-2005 resulting from both the dwindling effects of the ICT revolution and a broader economy-wide slowdown.

To further investigate the implications of these results, we split our regressions to study the commodity-producing (CP) and services-producing (SP) sectors separately. To save space we present results for just one of the three KLEMS-based ICT-intensity variables, that based on the 1999-2005 contribution of ICT capital to value-added growth, that is, the "Contribution Dummy". The first two panels of Table 9 show regression results for the Contribution and Fernald variables for U.S. CP industries, while the third and fourth panels show the results for the same variables for the SP industries.

The overall effects of the first panel for the Contribution dummy for CP show that ICT-using industries began with an average productivity growth of 1.72, rose to 2.53 and then fell back down to 1.58 post-2005. On the other hand, non-ICT industries started out higher with growth at 2.59, experienced no statistically significant speedup from 1995-2005, and then plummeted to growth of just 0.73 post-2005. These KLEMS results are consistent with the earlier finding that the ICT-using industries were not as adversely affected by the economy-wide slowdown, and maintained higher growth rates post-2005 despite starting out at a lower point. However, there is no statistical significance on the "ICT*Mid" variable, suggesting that ICT investment in CP industries made no significant contribution.

The results from the Fernald Dummy are different: the ICT*Mid coefficient is larger and more significant at 1.38, suggesting that ICT intensity drove a post-1995 speedup in CP industries. Moreover, the ICT*Mid variable is almost twice as large in magnitude as the estimate for the Fernald Regression in Table 8, indicating a greater ICT stimulus to post-1995 growth in CP than in the total economy. However, while non-ICT-intensive commodities had productivity declines of only about a percentage point post-2005, ICT-using industries on average fell about -3.51 points to a growth rate slightly lower than non-ICT-intensive industries.

Thus the two ICT indicators tell opposite stories for the U.S. The KLEMS Contribution Dummy concludes that ICT use had no contribution to a revival in the CP industries. The Fernald Dummy suggests that ICT-using CP industries experienced a massive post-95 speedup and an even greater post-05 slowdown than non-ICT-intensive commodities.

Turning our attention to the Contribution Dummy results for the SP industries in the third panel of Table 9, we see that ICT-using industries had a significant post-95 productivity acceleration 1.49 points greater than non-ICT-intensive industries, which explains all of the speedup in services. On the other hand, while the post-2005 slowdown was only about -0.5 points for non-ICT industries, returning them to their pre-1995 rates of productivity growth, the slowdown was much more marked for ICT-intensive industries, which experienced an average slowdown of -1.36 points. The overall effects grid shows that, ICT-using services started at higher levels of productivity growth than non-ICT-intensive services, accelerated to much higher levels, and then fell back to their pre-1995 levels. However, non-ICT services experienced a continuous slowdown and were hit hard by negative productivity growth over all through periods. The Fernald variable differs: non-ICT SP growth sped up 0.85 points post-1995 and then fell -0.96 points post-2005, while ICT SP experienced no additional acceleration or deceleration. That is, ICT-use had no effect on the revival in the SP industries.

Hence, these two measures of ICT reach different conclusions for the U.S. The Fernald variable attributes most of the speedup to ICT-using commodities. The post-2005 economy-wide slowdown affected all industries, with ICT-using commodities slowing down much more than they sped up. ICT-use had no significant effects for services industries. On the other hand, the KLEMS Contribution Dummy shows that ICT-use had no effects in commodities, while ICT-using services saw a massive speedup and slowdown relative to non-ICT-intensive services.

Results for the EU-10

Table 10 refers to the EU-10 and is laid out exactly like Table 8. For all the variables, we see a continuous negative pattern emerge for non-ICT-intensive industries, as seen in the overall effects and the negative coefficients on the "Mid" and "Late" variables. The results are more mixed for the ICT interaction coefficients. The Contribution, and Fernald Dummies show positive, significant coefficients on ICT*Mid, revealing that productivity growth in ICT-using industries was higher in 1995-2005 relative to pre-1995 than in non-ICT-intensive industries. A test that the sum of the Mid and ICT*Mid coefficients was zero could not be rejected at the five percent threshold for any of these regressions, meaning that while the rest of the European economy was undergoing a slowdown, ICT-intensive industries had neither a discernible speedup or slowdown relative to the pre-1995 era. The Share and RoC dummies display insignificant additional effects for ICT-using industries post-1995.

The results diverge for the ICT*Late coefficient. The Share Dummy suggests there was no additional post-05 slowdown for ICT-using industries. The RoC Dummy points to a slightly shallower productivity fall for ICT-using industries than non-ICT-intensive industries. The Contribution and Fernald Dummies suggest statistically significant falls in ICT-intensive industries and, in the case of the Fernald Dummy, a fall that leads ICT-using industries to average negative growth rates during the 2005-2015 period compared to 0.92 for non-ICT-intensive industries. Unlike the U.S., where a clear post-1995 ICT-speedup effect could be seen across different measures of intensity, ICT-use at best slightly mitigated a broader EU-10 slowdown.

Turning to the CP vs. SP industries breakdown in Table 11, we find no significant speedup for ICT-intensive industries in the CP industries with the Contribution variable. Instead, the overall effects show that non-ICT-intensive industries experience a slowdown in productivity post-1995, while ICT-using industries experienced no speedup or slowdown post-1995 and a massive drop in productivity post-2005. These results are similar for the Fernald regression, which shows a very slight post-1995 speedup followed by a massive post-2005 slowdown for ICT-using CP industries. However, the ICT*Late coefficient is nearly twice the magnitude of the ICT*Mid variable, indicating that the post-05 slowdown led to far greater net falls in ICT-using commodities' productivity. Interestingly, the coefficients on ICT*Mid and ICT*Late are 1.38 and -2.42 for the U.S., while the same coefficients are 1.42 and -2.48 for the EU-10, meaning that the magnitude with which ICT contributed to a commodities speedup was nearly the same in both the U.S. and the EU. Another striking fact is that there are no significant effects for ICT-*producing* commodities, a stark contrast to the massive speedup and slowdown experienced by the U.S., which raises questions as to why the Electrical Machinery industry in the EU-10 missed out on the explosive growth experienced by that industry in 1995-2005.

The third and fourth panels of Table 11 refer to the SP industries, and the results for the Contribution and Fernald variables are again similar. There is only a gradual, negative slowdown across both ICT-using and non-ICT-using industries. ICT-using industries begin with productivity growth around 1.3 percent in 1979-95 and then in 2005-15 slow down to 0.85 percent for the Contribution variable and 0.72 for the Fernald variable, while non-ICT-intensive industries hovered around zero growth across all three time periods. In sum, both variables find that ICT-use mitigated slowdowns in EU-10 CP industries, while there were no significant effects of ICT in the ICT-using SP industries.

ICT Conclusions

When framed in the context of broader productivity trends, the Fernald ICT variable tells similar stories for the U.S. and Europe. In the U.S., the Fernald dummy shows that the role of intensive ICT use as a cause of the post-1995 productivity revival was primarily concentrated in the CP industries, but that post-2005, the benefits of the ICT-revolution had been reaped, and growth fell more than it initially rose. A very similar pattern can be seen for Europe, with ICT-using CP industries staying abreast of non-ICT industries post-1995 and falling harder post-2005, although amidst the backdrop of an economy-wide slowdown in the EU-10. The estimates for the ICT*Mid and ICT*Late are nearly the same for the U.S. and EU-10 in the CP industries, meaning that ICT use had similar effects in boosting growth relative to non-ICT-using CP industries. However, ICT use had no discernible effect on SP industries in either the U.S. or the EU-10.

The Contribution dummies, on the other hand, show no impact of ICT-intensity in U.S. CP industries. The variable shows that ICT-use significantly contributes a productivity revival in U.S. SP industries, and is able to maintain growth at pre-1995 levels in the EU-10. However, the gains from the revival in the U.S. disappear after 2005. For the economy as a whole, the Contribution dummy shows that ICT-using industries in the U.S. averaged 0.77 percent growth from 2005-2015 and 0.85 percent in the EU-10, illustrating that these ICT-using industries converged to a similar level of productivity by 2005-2015.

The set of conclusions for the EU-10 are straightforward. First, the EU-10 clearly lagged behind in ICT-investment, as demonstrated by the uniformly lower values for ICT indicators in Table 7. Second, ICT-intensity did not spur a productivity revival in EU-10 SP industries, and at best mitigated the slowdown in EU-10 CP industries. Finally, while the Electrical Machinery industry helped drive growth in the U.S. commodities industry, the same industry experienced lower growth in the EU-10 and did not respond to the ICT revolution.

While the two indicators arrive at similar conclusions for Europe in the importance of the ICT effect for commodities and not for services, there is no such agreement for the U.S. The Fernald measure finds a substantial ICT effect in commodities and none in services, while the Contribution variable finds the reverse. The extent of this disagreement between these indicators of ICT intensity, and the disagreement about the extent to which the post-2005 U.S. slowdown occurred more in the ICT-intensive than non-ICT intensive industries, suggests caution in attributing all of the post-1995 U.S. revival and post-2005 slowdown to the role of ICT.

9. Conclusions

This paper examines the industry origins of the slowdown in labor productivity growth for the U.S. in data going back to 1950 and for the Western European nations (that we call the EU-10) back to 1972. Our point of departure is that, following a catch-up spurt of rapid growth in the first 25 years after World War II, when Europe was chasing the technological frontier that the U.S. had established before and during the war, in the next time interval 1972-95 the characteristics of EU-10 productivity growth were surprisingly similar both in overall pace and also in industry composition to that achieved by the U.S. in the prior 1950-72 time period. These results indicate that, if in 1972 you had known the rate of productivity growth by industry achieved in 1950-72 for the U.S., you would have been able to do a quite a good job of predicting productivity growth by industry in the EU-10 in the subsequent 1972-95 period (a relationship exhibited in Figure 9a). A novel aspect of the paper is to take the 1972-95 period in the EU-10 as equivalent to the 1950-72 interval in the U.S. and to calculate an "early-to-late" slowdown from these two different starting points.

As suggested by Shakelton (2013) and a large previous literature, productivity growth in the U.S. 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 U.S. of only 50 percent. Europe rapidly caught up in 1950-72, by 1972 reaching a level ratio of 81 percent, and in 1972-95 more than caught up, reaching a level ratio of 106 percent of the U.S. in 1995. Thus we interpret the second EU catch-up interval of 1972-95 as matching in both its overall growth rate and industry composition what the U.S. achieved in 1950-72.

Contrary to the literature that laments European shortcomings in the scope and application of innovation and arteriosclerosis in its product and labor markets, one of the most striking results of this paper is that the slowdown in EU-10 productivity growth from the 1972-95 average growth rate to 2005-15 was exactly the same (-1.68 percentage points) as the slowdown in U.S. productivity growth from its 1950-72 average growth rate to 2005-15 (-1.67 percentage points). The start-interval and end-interval growth rates were very close, from 2.54 to 0.87 percent for the U.S. and from 2.31 to 0.63 percent for the EU-10. The slowdown over the same time intervals in the subset of industries that produce commodities was also almost identical (-2.15 percentage points for Europe vs. -2.13 points for the U.S.)

Even more striking about what we call this "early-to-late change" is that there is a correlation coefficient of 0.81 across industries between the U.S. and EU-10 in the magnitude of their growth slowdowns (a pattern shown in Figure 10). The correlation coefficient rises to 0.85 for industry contributions to the total slowdown, that is, when industry productivity growth rates are weighted by the value added share of each industry.[16] Thus the productivity growth slowdown is a transatlantic 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

[16] These correlation coefficients exclude the mining industry.

to a retardation in technical change that affected the same industries by roughly the same magnitudes in the U.S. and in the EU-10.

The analysis of the paper back to 1950 for the U.S. and back to 1972 for the EU-10 is achieved by merging together several releases of KLEMS data. This allows us to go beyond most of the recent literature on U.S. productivity growth behavior, which has focused on the post-1995 revival and post-2005 slowdown and has been handicapped by the 1987 start date of BLS industry data. By going back to 1950 we can highlight the industry origins of relatively rapid U.S. growth during 1950-72 and of its post-1972 growth slowdown.[17] For the EU-10, KLEMS data allow us to extend the analysis back to 1972 and highlight similarities in the European growth experience in 1972-95 as compared to U.S. industry behavior in 1950-72. By creating a single EU-10 aggregate with data comparable to the U.S., we avoid the complexity in much of the literature on European growth that focusses on differences among individual European countries.

The industry decomposition in the KLEMS data is less detailed than the 60-industry breakdown of the BLS data for the U.S. We have 16 industrial sectors, including the manufacturing aggregate, as well as 11 sub-industries within manufacturing, for a total of 27 industries. Having 27 rather than 60 industries to examine is an advantage as it facilitates making generalizations and reaching conclusions. Throughout the paper we separate the analysis between the 16 sectors and 11 manufacturing sub-industries in order to isolate patterns and to highlight the industrial outliers.

To simplify further, we place considerable emphasis on the distinction between commodity-producing industries and those producing market services. We find that all of the post-1972 U.S. productivity growth slowdown was due to commodities and absolutely none to services, and most of the post-1995 U.S. productivity growth revival was due to commodities. Productivity in commodities was faster than in services 1950-72, slower than in services 1972-95, and faster again in 1995-2005. Both commodities and services contributed equally to the post-2005 U.S. slowdown.

In the EU-10 productivity growth slowed after 1995 and again after 2005 in both commodities and in services, but the overall 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 (1950-72 for the U.S. and 1972-95 for the EU-10) growth in commodities was faster and thus had further to fall. This reflects the role of inventions and innovations earlier in the 20th century and spilling over from the 19th century that had a greater impact on commodity-producing industries than those producing market services. The dominant role of commodities in driving the post-1995 U.S. growth revival is somewhat surprising in light of the emphasis in the literature on technological

[17] As explained in section 2, the KLEMS data for the U.S. go back to 1947, but we exclude 1947-50 because of implausible behavior in the data for productivity growth of the public administration sector.

change in the service industries propelled by the introduction of personal computers, terminals, the internet, and related ICT hardware and software.

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 post-1995 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 1950-72, emerge after 1972, disappear between 1995 and 2005, and then become even worse after 2005 than it was during 1972-95.

While commodities dominated the post-1972 U.S. slowdown and post-1995 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, particularly in papers by Byrne *et al.* (2016) and Syverson (2017). They both conclude that the role for 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 slowdown. The details of their arguments go beyond the scope of this paper, 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.

The best-known difference between productivity behavior in the U.S. and Europe, going beyond Europe's catch-up lag between 1950 and 1995, is the failure of Europe to enjoy a productivity growth revival after 1995. From 1972-95 to 1995-2005 U.S. market sector productivity growth revived from 1.66 to 2.89 percent per year, while that in the EU-10 slowed from 2.47 to 1.61 percent. In part Europe was experiencing a slowdown like that which afflicted the U.S. after 1972; notice that EU-10 growth in 1995-2005 was roughly the same as in the U.S. for 1972-95. But the failure of the EU-10 to respond to the digital revolution is noteworthy and puzzling. We show that there was a high correlation across industries between the U.S. and

EU-10 in 1995-2005 growth rates, indicating that the industries that did best in the U.S. 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; the regression line in the scatter plot of Figure 9b has a highly significant coefficient of 0.48 when EU growth by industry for this interval is regressed on U.S. growth by industry.

Europe is sometimes claimed to have the wrong industrial structure, with less of its economy than in the U.S. producing in "high-tech" sectors and more in "medium-tech" and "low-tech" sectors. To evaluate this claim we have recalculated EU-10 productivity growth by applying U.S. industry shares to EU industry growth rates. This makes little difference after 1995 but makes a large difference for 1972-95, because in that time interval the EU-10 had a considerably higher share of its economy producing commodities and less producing services, and commodity industries had double the growth rate as services during that interval. Thus with the U.S. industrial structure relatively light on commodities the EU-10 would have had slower growth in 1972-95, a bit faster growth in 2005-15, and an early-to-late overall slowdown of -1.09 percentage points rather than the actual -1.68 points. This smaller slowdown because of a hypothetical alternative industrial structure occurs because Europe would have done worse before 1995, not because it would have done appreciably better after 1995.

The KLEMS data allow us to carry out a sources-of-growth calculation which decomposes labor productivity growth into the respective contributions of multi-factor productivity (MFP), capital deepening, and changes in labor composition. For the U.S. MFP makes the dominant contribution to the post-1972 productivity growth lowdown and post-1995 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 contribution measures the impact of innovation, we could conclude that flagging innovation deserves half the blame for the early-to-late slowdown in both the U.S. and EU. The high correlation between the U.S. 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 postwar growth, particularly in the commodity-producing industries.

But it would be a mistake to limit the role of innovation to the MFP contribution. In the Solow growth model in long-run equilibrium the capital-output ratio is constant, and so the growth rates of capital and output are equal. Anything that reduces output growth, including slowing innovation, will reduce the growth rate of capital and thus diminish the contribution to productivity growth of capital deepening. Thus while the contribution of MFP to the early-to-late productivity growth slowdown is 50 percent of the total in the U.S. and 55 percent 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 labor productivity growth.

To study the role of the ICT revolution in contributing to the U.S. productivity revival of 1995-2005 and also to understanding the industry origins of the EU post-1995 slowdown, we develop three indicators of intensity of ICT use by industry from KLEMS data and compare their impact with an indicator for the U.S. previously developed by John Fernald. The effect on productivity growth of industries with high intensity of ICT use is contrasted with other non-ICT industries and also with two ICT-producing industries (electrical machinery and information/communications).

One of the biggest post-2005 advantages of the U.S. compared to the EU-10 is its much higher contribution to productivity growth from the electric machinery industry (where the production of ICT hardware is located in our industrial classification), partly because of its larger relative size but mainly because of its much faster industry productivity growth. That industry also made a major contribution to the post-2005 growth slowdown. All the ICT-intensity measures agree that for the U.S. most of the post-1995 revival was contributed the ICT-intensive industries, while the measures differ regarding the post-2005 slowdown. The KLEMS-based measures attribute that slowdown mainly to the non-ICT-intensive industries, whereas the Fernald measure shares the blame roughly equally between the two industry groups.

In Europe several of the measures suggest a split, with non-ICT industries experiencing a substantial post-1995 slowdown while ICT-intensive industries have enough of a boost to offset that slowdown and exhibit unchanged rather than diminished productivity growth. All the EU regressions support an industry-wide post-2005 further slowdown with the different measures differing on whether the ICT-intensive industries suffered from an additional slowdown. A big difference in the EU-10 from the U.S. is the absence of any post-1995 increase at all in the productivity of the electrical machinery industry, but Europe also did not suffer from a big post-2005 drop in productivity growth in that industry as happened in the U.S.

The detailed analysis in the paper highlights particular outlier industries that differ either from other industries within the U.S. or EU-10 or exhibit different patterns across the Atlantic. We have noted the larger size and much faster productivity growth of the electric machinery industry in the U.S. than in the EU-10 and its role in contributing to the post-2005 slowdown, although its annual 2005-15 U.S. productivity growth rate was still a respectable 7.1 percent. Mining differed from other U.S. industries by growing slowly during 1995-2005 and then having a major growth revival in 2005-15, presumably resulting from the fracking revolution. Retail/wholesale are the biggest exception to the generalizations about the dominant role of commodity-producing industries in explaining the U.S. post-1972 slowdown and post-1995 revival, as they achieved productivity growth faster than the commodity average throughout 1950-2005 before they came crashing down with a sharp growth slowdown after 2005.

We have already noted that most U.S. industries out-performed the EU-10 by a large margin during 1995-2005 before falling back after 2005 to growth rates similar to those in Europe. During the earlier 1972-95 period the EU-10 consistently outperformed the U.S. in commodity-producing industries and in transportation services, while the U.S. did much better during that interval in retail/wholesale, information/communication, and finance/insurance. Within U.S. manufacturing petroleum refining exhibited incredible gyrations in productivity growth down after 1972, up after 1995, and down after 2005 that would seem to have little to do with the digital ICT revolution, and the chemicals industry experienced the same fluctuations albeit with a much smaller order of magnitude.

This paper 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 post-1995 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 this study has helped to point to those particular industries that are most in need of further insight and evaluation.

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Data Appendix

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 rate 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. 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 main 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, numbers were simply joined. 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:

- *VA_Q*, growth rate of real value added;
- *VAConTFP*, contribution of TFP growth to real value added growth;
- *VAConLC*, contribution of labor composition growth to *VA_Q*;

- *VAConH*, contribution of hours growth to *VA_Q*;
- *VAConKIT*, contribution of ICT capital services growth to *VA_Q*;
- *VAConKNIT*, contribution of non-ICT capital services growth to *VA_Q*;
- *VAConK*, contribution of capital services growth to *VA_Q*, which is the sum of *VAConIT* and *VAConKNIT*;
- 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:

$$VAQ_t = VAConTFP_t + VAConLC_t + VAConH_t + VAConKIT_t + VAConKNIT\_t$$

Let *s* be labor's share, *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:

$$y_t = tfp_t + s(lc_t) + s(h_t) + (1-s)k_t^{IT} + (1-s)k_t^{NIT}$$

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:

$$y_t = tfp_t + s(lc_t) + s(h_t) + (1-s)k_t$$

where capital growth $k_t = k_t^{IT} + k_t^{NIT}$ by definition.

On the other hand, *LP1_Q* (or *lp*), which is value added per hour, can be written as:

$$\begin{aligned} LP1Q_t = lp_t = y_t - h_t = tfp_t + s(lc_t) + s(h_t) + (1-s)k_t - h_t = tfp_t + s(lc_t) + (1-s)(k_t - h_t) \\ = VAQ_t - h_t = VAConTFP_t + VAConLC_t + (1-s)(k_t - h_t) \end{aligned}$$

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 $\frac{1-s}{s}$, 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,

$$LP1Q_t - VAConTFP_t - VAConLC_t = ConK/H_t$$

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 contributions to add up to labor productivity, it also prevents any measurement 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 use *LP1_Q* in preference to *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 calculate the level of UK labor productivity in 1995 as the average of the values in 1994 and 1996.

The ICT Variables

As part of the analysis on the impact of different contributions and trends to labor productivity, we include a variety of "ICT" dummy variables calculated from the KLEMS data. As outlined in the text, using dummy variables in all of these cases marks industries as distinctly "ICT-intensive" and hence allows a clean interpretation of regression coefficients. The first of the variables is an ICT-Share dummy, equal to "1" if an industry's ICT Share is above the industry median and "0" otherwise. The share is equal to the sum of the KLEMS nominal capital formation variables *I_IT* (computing equipment), *I_CT* (communications equipment), and *I_Soft_DB* (computer software and databases), divided by *I_GFCF* (all assets). That is, the ICT share for a given year is the share of capital expenditure spent on information-technology related capital.

In a similar vein, the "ICT Nominal Rate of Change Dummy" is equal to 1 if an industry's nominal rate of change of total expenditure on ICT capital is greater than the median for the period of 1991-1995. Finally, the "ICT Contribution" variable, or "Contribution Dummy," is equal to "1" if the 1999-2005 contribution of ICT capital growth to value-added (i.e. the real growth in ICT capital services multiplied by its share of production) is greater than the industry median. Here, we are forced to use the 1999-2005 period, as there is no ICT capital contribution data available for the United States prior to those years.

The final variable is based on Table A1 from Fernald (2014). Our own Table A1 shows the KLEMS industries in the left column, and then the line numbers of Fernald's table on the right to display which the industries on the left were matched and subsequently marked as IT-intensive. Table A2 shows the raw values for each of the KLEMS ICT variables and includes an asterisk to mark those ranked above the median, hence those considered as ICT-intensive.

Agggregating 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 sub industries 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 "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 was 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 required only the summing up of 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 A3 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 A3. 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.