Paper to Accompany the Presentation "The Potential for Productivity Improvement: Results for Japan, Germany and the US."

This paper differs from the slide presentation. It was written for non-economists and covers background material familiar to an economics audience. It emphasizes labor productivity.

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Brookings

This paper is preliminary, may contain errors, and is subject to change

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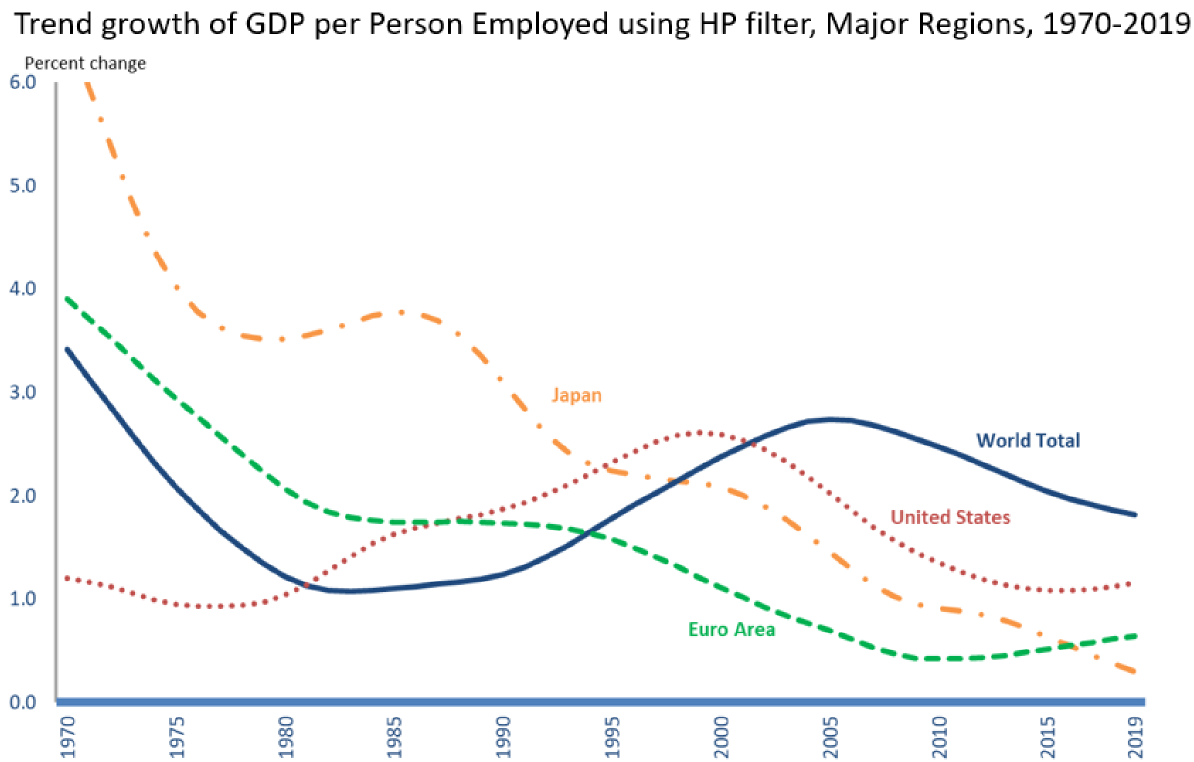
I. Introduction

Economic growth provides broad and substantial benefits. When growth is strong, household incomes rise, and wages increase; it becomes much easier to balance budgets and to meet the needs of the poorest members of society. Overall economic growth does not guarantee that everyone in an economy will be better off, but it helps.

Strong economic growth, in turn, comes from two sources, the growth in the workforce and the growth in output per worker (that is, labor productivity). The demographic trend in advanced economies has been towards lower birth rates leading to slower growth in the population and in the labor force, with the population aging as its growth slows. Immigration can supplement the growth of the domestic population, but this can generate social stresses and political problems. In the advanced economies, labor force growth is much slower than in past, particularly in Japan but also in Germany and the United States, with a negative impact on the rate of increase of national incomes.

With slower labor force growth, that leaves productivity as the main driver of overall economic growth and, unfortunately, it too has slowed. Figure 1 shows the pattern of trend growth in output per employed person as calculated by the Conference Board for the United States, Japan, Europe, and the World Total. Productivity growth in the United States has been slow since the early 1970s, except for a period in the late 1990s and early 2000s. Japan and Germany had much faster growth in the 1970s, but the growth rate has declined sharply since then. With the slowing of growth in China, the trend of growth in the index for the total world economy has also slowed.

Figure 1: Trend Productivity Growth is Falling in US, Japan and Europe and, recently, in the World Total



Source: The Conference Board Total Economy Database (adjusted version) April 2019

Focus of this Project. The pattern of productivity growth in the three largest mature economies, the United States, Japan, and Germany, is the focus of this project. There have been many efforts to understand why growth has been so slow in recent years, and while there is some suggestive and interesting evidence of what factors may be at work, there is no consensus explanation for the pattern of slow growth that is widespread both by country and by industry (Baily and Montalbano 2016). This project will examine data on productivity growth in the three economies, looking at the aggregate, economy-wide data and at different industries. Data on the growth of labor and total factor productivity are available, plus estimates of the comparative levels of productivity in the three economies. These data can cast light on the nature of the productivity growth slowdown and may help disentangle its causes. Although these results can guide policy measures that are designed to improve the rate of growth of productivity, there is no guarantee the causes of the slowdown will be uncovered.

Uncover industries where there is potential for faster growth. Which industries are being held back by barriers to productivity growth? Are there industries where policy could facilitate faster growth, for example by encouraging technology development and research and development (R&D), or by changing the regulatory environment? The first approach to identify industries with growth potential comes from looking at industry growth rates. One warning sign is an industry where productivity growth has been negative for a period of years. What is causing this regression of productivity? Another sign worth exploring is if an industry experienced rapid growth in a past period but has slowed sharply. Has the past growth exhausted the possibilities for faster growth in the future, or is there another wave of growth developing? What could be done to facilitate the next wave of growth.

The second approach to finding industries with growth potential makes use of data on productivity levels. We take it as part of the natural process of economic growth that industries that have productivity levels below best practice have the potential to catch up.[1] With total factor productivity, productivity convergence will occur as technologies and best business practices are diffused across countries. With labor productivity, capital investment can bring lagging industries up to, or closer to, the productivity frontier.

This second approach is important because it provides a possible way to improve productivity that avoids debate about whether future innovations can foster faster growth. If another country has already achieved higher productivity, then the challenge is to find a way to adopt technology already in use.

A caveat to this argument is that there may be natural barriers to achieving a high productivity level in some economic activities. Silicon Valley is hard to replicate. The US has advantages in its

[1] Where best practice here is defined as the industry with the highest level of productivity. The productivity frontier.

endowment of arable land and energy resources. Managers may be less skilled in some countries than in others. This caveat should not be overstated. As we have known since David Ricardo, difference in endowments can lead to market segmentation rather than the perpetuation of low productivity industries. Managers are mobile, indeed many of the best United States CEOs come from other countries, or their parents did. Direct foreign investment can bring proprietary technology or best practice business processes into a country.

Definitions of Productivity. The simplest and most intuitive measure of productivity is labor productivity, measured either by output per employee or output per hour worked. Output is measured as the value of output produced by an economy or industry or firm over a given period, usually a year. Output is tracked over time by adjusting the value of output in nominal local currency for the impact of inflation. Output, in other words, is measured in real or inflation-adjusted units of currency. The number of employees reflects the average level of employment over the time-period and is often adjusted to count part-time employees as a fraction of full-time employees. Output per hour worked takes account of the actual number of hours each employee works on average over the period. Over a period of years, the number of hours worked per worker may change substantially, as has been the case for both Japan and Germany, where average annual work hours have declined. An advantage of labor productivity at the aggregate level, besides its simplicity, is that it links to GDP growth and wage growth. GDP growth is roughly the sum of the growth rate of GDP per worker and the growth rate of employment. Growth in output per hour in the business sector is closely linked to the growth of real average earnings.

Comparing levels of productivity across countries requires a way to compare output measured in dollars, with output in yen or euros. Some comparisons use foreign exchange rates for this purpose and that may work well to compare tradable goods industries. However, exchange rates fluctuate over time in ways that can give a distorted picture of relative productivities and many goods and most services are not traded. The approach favored by the OECD and by productivity researchers is to measure purchasing power parity (PPP) exchange rates to capture the prices of comparable goods or services across the countries being studied. Finding accurate price comparisons and insuring comparability of products is a challenge and there are differing findings depending on who is making the comparisons. Taking account of taxes is one of the more difficult aspects of this task along with ensuring comparable quality of goods or services. Also, the price comparisons are made in a single year and then the PPP exchange rate is then imputed throughout the time-period being compared. There is room for error in these comparisons.

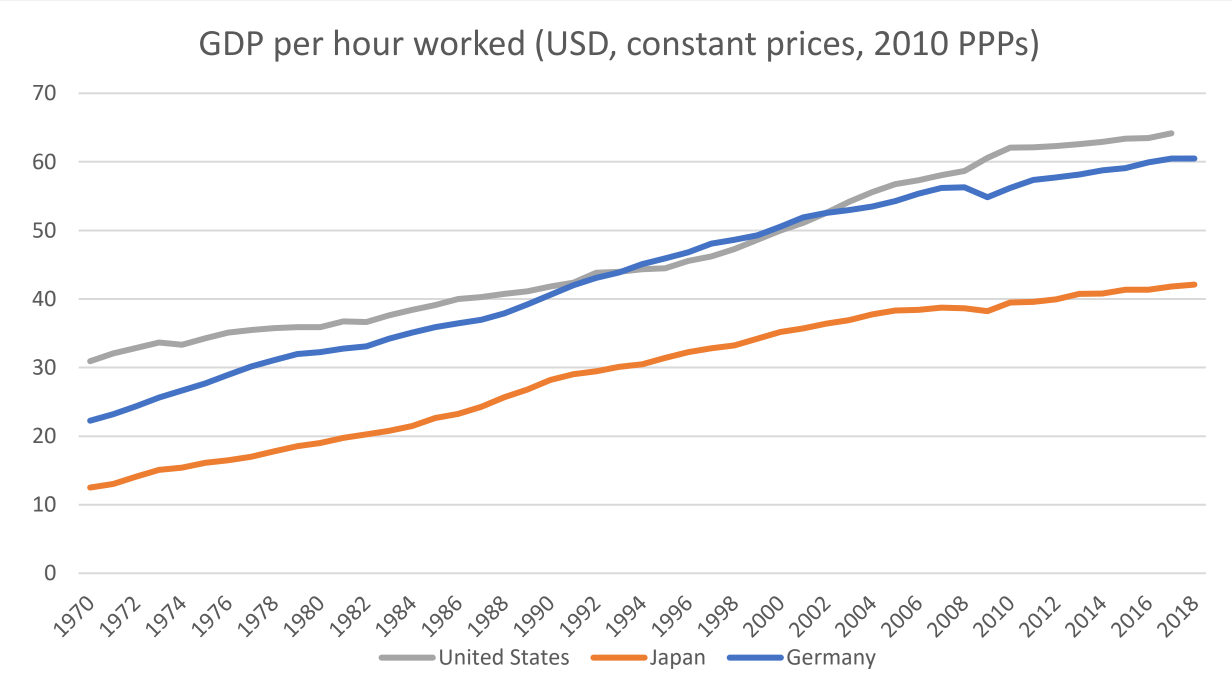
Although labor productivity is intuitive and useful it is not the productivity measure favored by economists researching productivity. The intellectual framework for productivity research is the production function, where output is determined by the level of productive inputs and the technology used to combine these inputs to produce output. Total factor productivity (TFP) growth reflects the increases in output obtained beyond the increments obtained from additional inputs. (The term multifactor productivity is also used in the literature, but we will use TFP as our terminology.) Using the formalization from the Solow growth model, the growth rate of TFP is the growth rate of output minus the growth rate of inputs, where each input is weighted by its share in costs. The growth rate of TFP is then a measure of technological change, either from innovative processes or products. Economists favor TFP because it separates the impact of output growth that is the result of additional inputs from growth due to technological change. Since it is calculated as a residual, measurement errors can have a big impact on estimated TFP growth.

If output is measured at the aggregate level, or if it is measured by value added at the industry or firm level, there are only two inputs to production, capital and labor. In that case, it can be shown that the growth rate of labor productivity (output per hour) is the sum of the growth of TFP plus the contribution of capital deepening (the increase in capital per hour worked weighted by the share of capital in cost). This is a valuable decomposition, indicating whether, say, a decline in labor productivity growth stems from a drop in technological progress or from a decline in the contribution of capital.

II. Productivity at the Aggregate Level

Labor Productivity Comparisons. Figure 2, below, shows labor productivity at the aggregate level (GDP per hour worked) for Japan, Germany, and the United States from 1950 until the present, based on OECD data using purchasing power parity exchange rates for 2010. In 1950, both Japan and Germany had productivity levels that were only a fraction of the United States, but in subsequent years productivity growth was much higher and they reduced the gap. Germany reached the US level of output per hour by the early 1990s and moved ahead of the United States briefly, before falling slightly behind at the end of the period. (Germany has greatly reduced the number of hours worked per employee and so output per employee was 73.7 percent of the US level in 2017.) Japan also moved closer to the US productivity level before its growth slowed relatively and it remains well below the US level at the end of the period. Changes in hours worked per employee were also important in Japan. Historically, Japanese workers spent much longer at work than did American workers but over time this gap was reduced, and the hours worked per employee were similar in the two countries in 2017 using OECD data.

Figure 2: Output per hour worked in Japan, Germany, and the United States



Source: OECD Stat.

A major theme of the economic growth literature of the 1970s and 80s was the “catchup hypothesis”. The United States economy, on this view, was the most advanced with the leading technology and productivity but over time other countries adopted best practice methods from America and were able to close the productivity gap.[2] Regression analyses and growth theory suggested that the speed of productivity growth of a country depended on how far away it was from the productivity frontier, defined by the United States. Japan and Germany grew very rapidly indeed in the 1960s into the 1970s, and some other countries such as South Korea and other European economies, also achieved rapid catchup.

Paul Romer (1986) famously cast doubt on the convergence predicted by the catchup hypothesis by showing that if you include all the countries in the world, there is no systematic tendency for countries below the productivity frontier to catch up to the leaders. In fact, there was evidence that many poor countries were falling further behind. The catchup growth model, he argued, was based on sample selection bias. Romer argued that most countries did not have the technology needed to converge to the frontier. One can also argue that many countries lack the legal framework and market institutions to support catchup, and some do not have a workforce with the necessary skills and education. Subsequent empirical research on cross-country growth found that catchup growth remained important even when looking at a broad sample of countries, but only after controlling for other growth determinants (Barro and Sala-i-Martin 1998). This is referred to as conditional convergence.

The data in Figure 2 are consistent with the story of catchup growth in both Japan and Germany in the years after World War II, some of it surely coming from economic recovery and some from the transfer of best-practice methods and technologies from the United States. By the 1990s, Germany had completed this catchup process, and the level of aggregate labor productivity in the United States and Germany has been roughly the same for several decades. Japan, on the other hand, did not complete the catchup process and in recent years the gap has widened. An important puzzle is to understand why Japan has not completed the catchup process.

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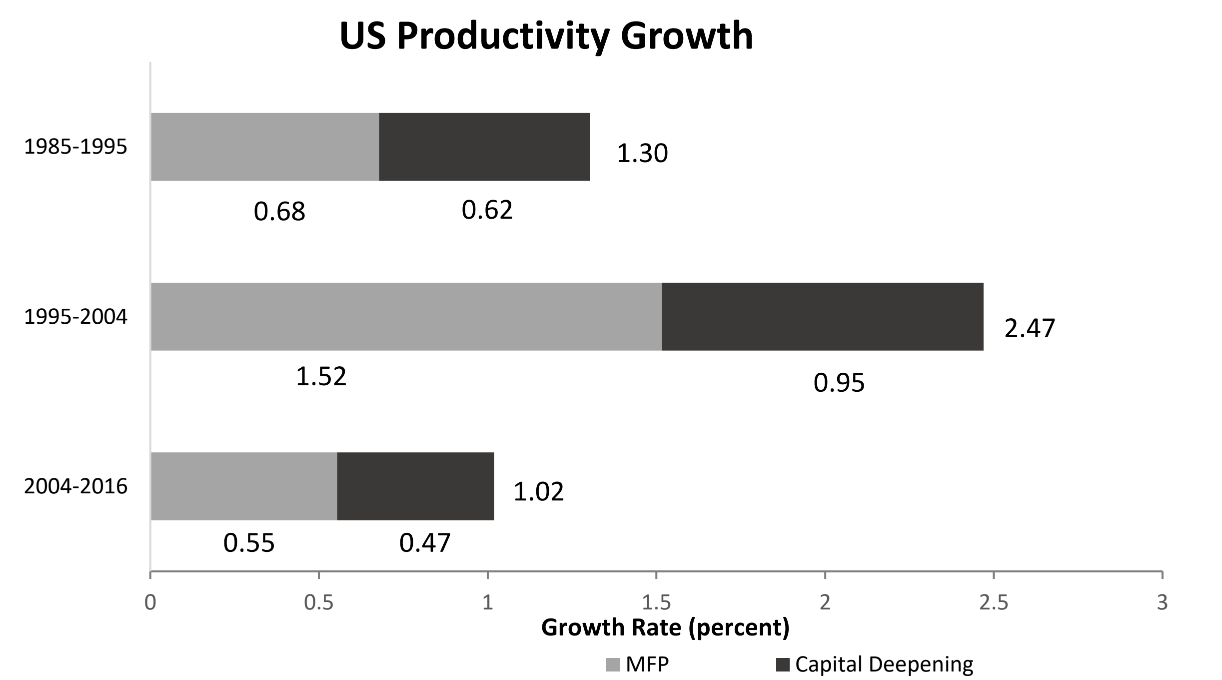
[2] A good exploration of catchup is in Baumol, Batey, Blackman and Wolff (1989). An extensive bibliography is included in this book.

The productivity growth slowdown. Figure 3 shows the pattern of both labor and total factor productivity growth for the US economy from 1985 through 2016, broken down into three time-periods.[3] Labor productivity growth was a modest 1.3 percent a year from 1985 to 1995 split almost evenly between the contribution of TFP and the contribution of capital deepening. There was then a sharp acceleration of growth lasting until about 2004, largely driven by an acceleration in TFP, but there was also a larger contribution from capital deepening.

Figure 3: Productivity Growth in the United States, TFP and Capital Deepening

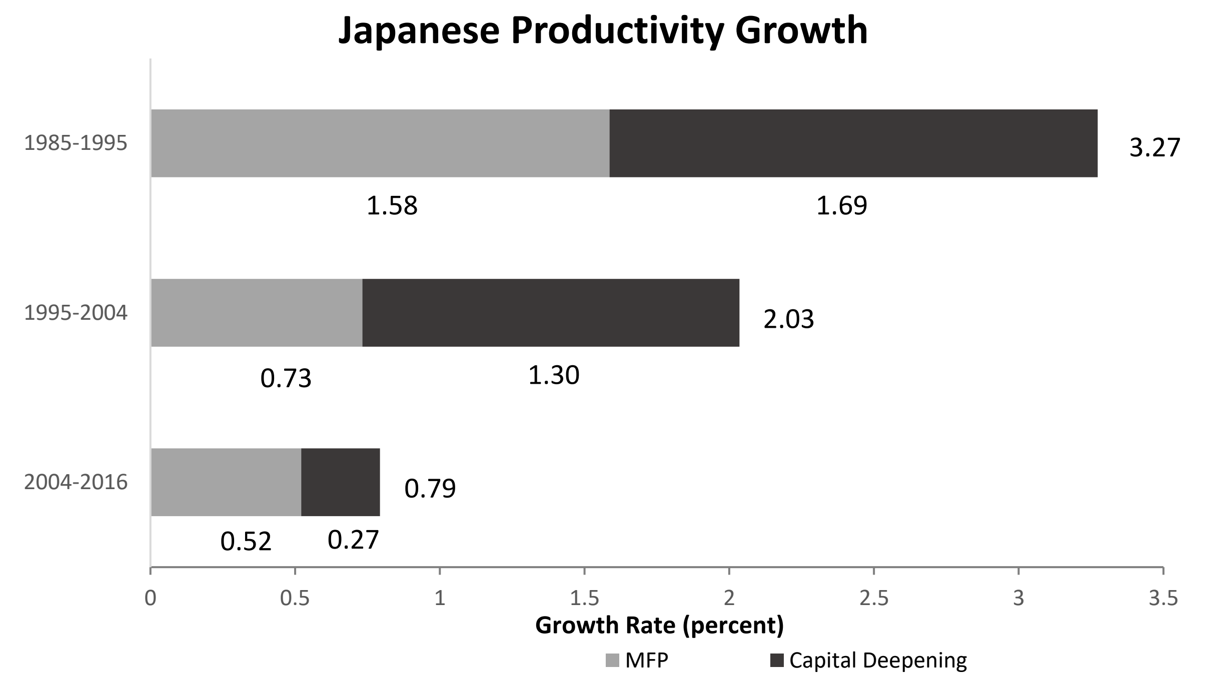


Source: OECD Productivity Statistics

Figure 4 repeats the same calculation for Japan, where productivity growth was much more rapid than in the United States from 1985 to 1995 (catching up) but growth slowed in the second period and slowed to just under 0.8 percent a year in the final period. Growth derived from both TFP and capital deepening in all periods, with both sources of growth slowing over time.

[3] The OECD data used here start in 1985 and end in 2016.

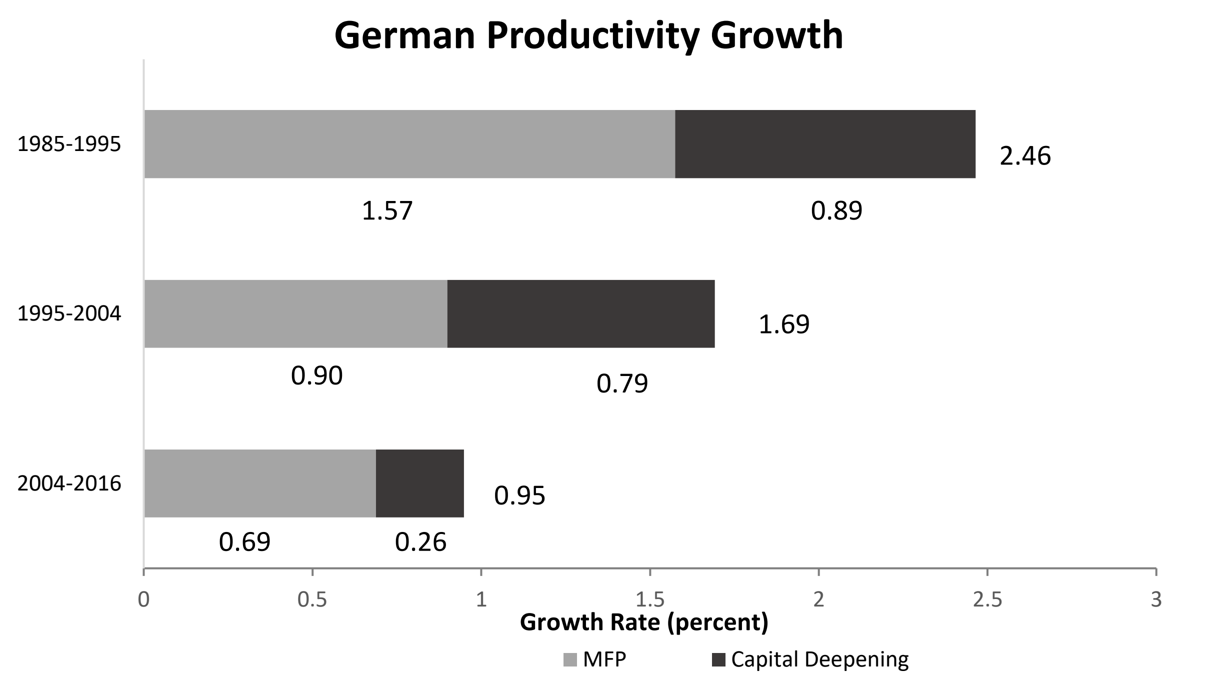
Figure 4: Productivity Growth in Japan, TFP and Capital Deepening



Source: OECD Productivity Statistics

Figure 5 repeats the same calculation for Germany and reveals a pattern similar to that for Japan. Both TFP and capital deepening contributed to growth over the full time-period, and there was slowing in both elements across the sub-periods. As in Japan, the contribution of capital deepening after 2004 was very small.

Figure 5: Productivity Growth in Germany, TFP and Capital Deepening



Source: OECD Productivity Statistics

Figures 3 through 5 show starkly the extent of the productivity growth slowdown in these three economies a strong common element among them. All three were experiencing very slow productivity growth in the most recent time-period. The United States pattern was different in that its growth rate had already slowed sharply before 1985 and it experienced a strong growth recovery lasting about ten years beginning the 1990s. Japan was different in that its productivity growth slowed just as sharply as the two other economies, even though it had not reached the level of labor productivity achieved by the other two (had not caught up, as seen in Figure 2). Japan's productivity growth rate was extremely slow in the 2004-16 period. There are some differences in the contributions of TFP and capital to growth and to the slowdown among the three economies, such as the very small contribution of capital to growth in both Japan and Germany in the 2004-16 period.

The decomposition of labor productivity growth into TFP and capital is standard practice but is not straightforward to interpret causally. If technological change slows down, reflected in slower TFP growth, this results in slow labor productivity directly, but it also reduces the incentive for businesses to invest because there are fewer new technologies to invest in (reflected in less capital deepening). If, on the other hand, some other factor causes a decline in investment, such as the global financial crisis, this may lead to a lower pace of TFP growth because new capital is usually a prerequisite for introducing new technologies or business processes. The magnitude and pervasiveness of the growth slowdown suggests both causal effects have been at work. The weakness in TFP growth and in capital deepening are mutually-reinforcing contributors to slower labor productivity growth.

In the United States since 2016 there has been a cyclical boom and a sharp cut in business taxes intended to encourage investment. There is no evidence that investment has been boosted, but the strong cyclical growth resulted in somewhat faster growth in output per hour in the business sector of the US economy in 2018 and the first half of 2019. It is too early to tell much but it is possible there has been a modest pickup in productivity growth.

Productivity Growth by Broad Industry Category

Consistent labor productivity and TFP data by industry is available from the OECD Structural Analysis (STAN) database for the US, Japan, and Germany. Japanese data are available from 1995 through 2016 but we have used data from the Japan Industrial Productivity (JIP) database to extend the sample back to 1991. We did not take the data back prior to 1995 for Japan for agriculture and construction because there appears to be a wide discrepancy between the STAN data and the JIP data where they overlap. The growth rates shown for the private business sector exclude agriculture and construction for all three countries. They differ from the figures shown in Figures 3 through 5, which are based on total GDP.

Figures 6 a, b, and c show the results for labor productivity (value added per hour worked) for the three countries. Over the full period 1991 through 2016 for the private business sector, labor productivity grows about a half percentage point faster in the United States. This is the result of faster growth prior to 2004, especially from 1995 through 2004. From 2004 through

2016, the rates of growth are very similar in all three countries: 1.1 percent in the United States, 1.0 in Japan and 1.2 percent in Germany. All three economies are in a very similar period of slow labor productivity growth, as we have already seen from the OECD aggregate data.

Figures 6 a, b, and c. Labor Productivity Growth by Industry US, Japan and Germany

USA : 1991 - 2016

Industry Labor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016
Agriculture, forestry and fishing	1.3	5.8	3.4	3.9
Mining and quarrying	8.0	-0.3	2.2	2.2
Manufacturing	3.6	6.1	1.9	3.7
Utilities	1.3	0.5	-0.7	0.0
Construction	0.6	-0.7	-1.1	-0.7
Wholesale and retail trade	3.6	5.1	1.0	2.9
Transportation and storage	1.1	1.6	-0.1	0.7
Information and communication	1.6	4.1	3.9	3.6
Financial and insurance activities	1.6	4.1	1.3	2.4
Real estate	3.4	0.7	2.0	1.7
Professional, Scientific and Administrative services	-0.7	1.5	0.6	0.7
Community, Social and Personal services	-0.7	-0.2	0.1	-0.1
Private Business Sector	**2.0**	**3.4**	**1.1**	**2.1**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Japan : 1991 - 2016

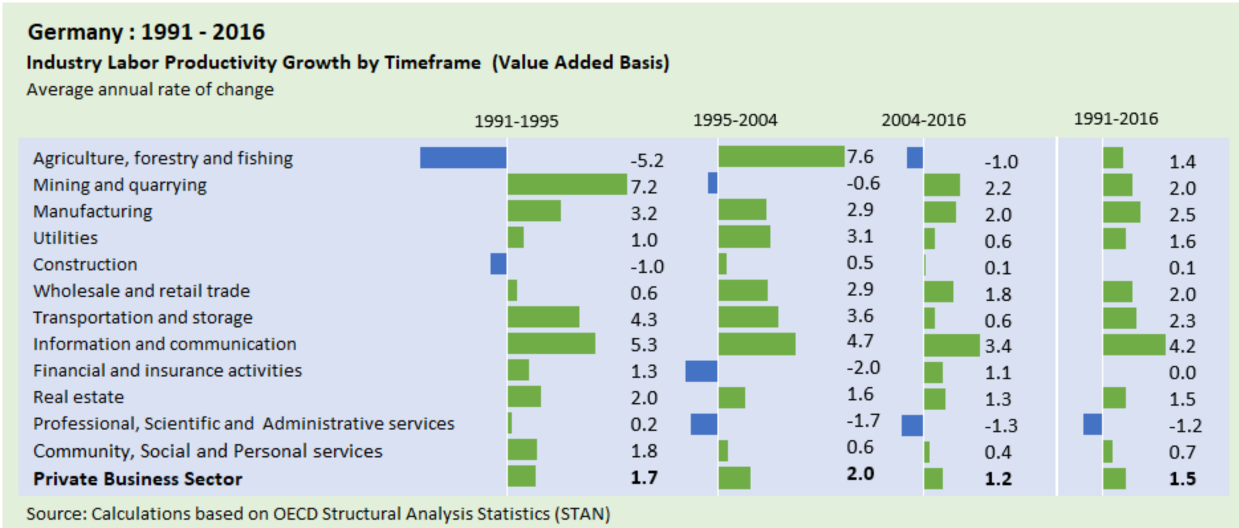
Industry Labor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016*
Agriculture, forestry and fishing	-	2.0	1.4	1.7*
Mining and quarrying	-6.4	4.0	-7.1	-3.0
Manufacturing	2.7	3.3	2.4	2.8
Utilities	0.7	2.5	-3.5	-0.7
Construction	-3.2	-1.2	0.9	-0.5
Wholesale and retail trade	5.0	2.0	0.4	1.7
Transportation and storage	1.4	-0.3	-0.8	-0.3
Information and communication	7.9	5.5	-0.2	3.2
Financial and insurance activities	0.6	1.1	0.3	0.6
Real estate	-	1.6	0.3	0.9*
Professional, Scientific and Administrative services	2.7	3.8	1.7	2.6
Community, Social and Personal services	0.5	-0.1	-0.5	-0.2
Private Business Sector	**1.8**	**2.2**	**1.0**	**1.6**

*1995-2016 for starred industries

Source: Calculations based on OECD Structural Analysis Statistics (STAN); Numbers before 1994 extrapolated using JIP data



Looking at the results by industry reveals that all three economies saw declines in manufacturing productivity growth post 2004, but the decline is much sharper in the United States. This is partly the result of the ending of the surge in computer and semiconductor productivity in the 90s, a surge that ended soon after 2000. This industry has also moved production overseas, making it a smaller fraction of manufacturing. Post-2004, Japan's manufacturing productivity growth rate has been the greatest, followed by Germany and then very slow growth in the United States industry.

Productivity growth in wholesale and retail, as well as transportation and storage, has been very slow in all three countries since 2004. The story of faster growth in earlier periods is now well-known as big box retailers and franchised smaller establishments displaced traditional retailers and integrated the wholesale function into their retail operations (Lewis et al. 2001). The surprise is that recent growth has been so slow, given the continuing transformation taking place in this industry as on-line retailing has been growing rapidly.

The information and communications industries benefit from advances in electronics and shows rapid growth in all three economies. Over the full period 1991-2016, the growth rates are similar across the three economies. The distribution of growth within the shorter periods varies, however, with Japan seeing an abrupt end to growth after 2004. The growth rate has also declined in Germany, although not as sharply as in Japan.

Productivity growth in the utilities industry has been very weak in the United States and Japan, zero in the former and negative in the latter. In Germany, by contrast, growth has been 1.6 percent a year over the whole period, with fast growth concentrated in 1995-2004. This industry is heavily regulated and has been impacted by shifting fuel prices and environmental concerns. Both Germany and Japan have shut down nuclear plants while the US industry has taken advantage of cheap natural gas. The United States and Japan both show negative rates of growth post 2004 (also the case for TFP), a puzzling result indicative of a productivity problem.

Financial and insurance activities in the US have seen relatively strong productivity growth over the full period, with the strongest growth 1995-2004, a period that included the early years of the real estate boom. Growth slowed after 2004, but still did a little better than in the other two economies. All three industries were impacted by financial cycles. The measurement of productivity in this industry is difficult and the results should be viewed with caution.

Agricultural labor productivity has been much more rapid in the United States over the full time-period at 3.9 percent a year, compared to 1.7 and 1.4 percent in Japan[4] and Germany. There is substantial volatility in the growth rates over shorter periods, which partly reflects weather patterns. Over the entire postwar period, productivity growth in United States agriculture has been among the most rapid of all United States industries, driven by advances in seeds, fertilizers, irrigation and other techniques. It may be that climate change will impact this industry in all three countries, but that is not yet evident in the productivity data through 2016.

Mining and quarrying saw good productivity growth in the United States and Germany but a decline in labor productivity in Japan. This industry is impacted by the depletion of the natural resource base, by the offsetting development of new technologies for extraction, and by regulation. In the United States data, the period of fastest growth is prior to 1995. The fracking revolution is not yet strongly impacting the most recent time-period.

Productivity in the remaining industries—real estate, professional services and community services—is difficult to measure and it is hard to see clear patterns in the reported data. The

[4] The STAN data for Japan are only available from 1995 to 2016.

real estate boom and bust in the United States does not show up strongly in the productivity growth data.

Total Factor Productivity Results

The comparable findings for total factor productivity are shown in Appendix 1. Looking at the nonfarm business sector over the full time-period, the growth rate of TFP is about a half a percentage point slower than the growth of labor productivity in both Germany and the United States, reflecting the similar contribution of capital deepening to labor productivity in both countries. The gap in Japan is larger, 0.8 percent, showing a stronger contribution of capital in Japan in this sector.

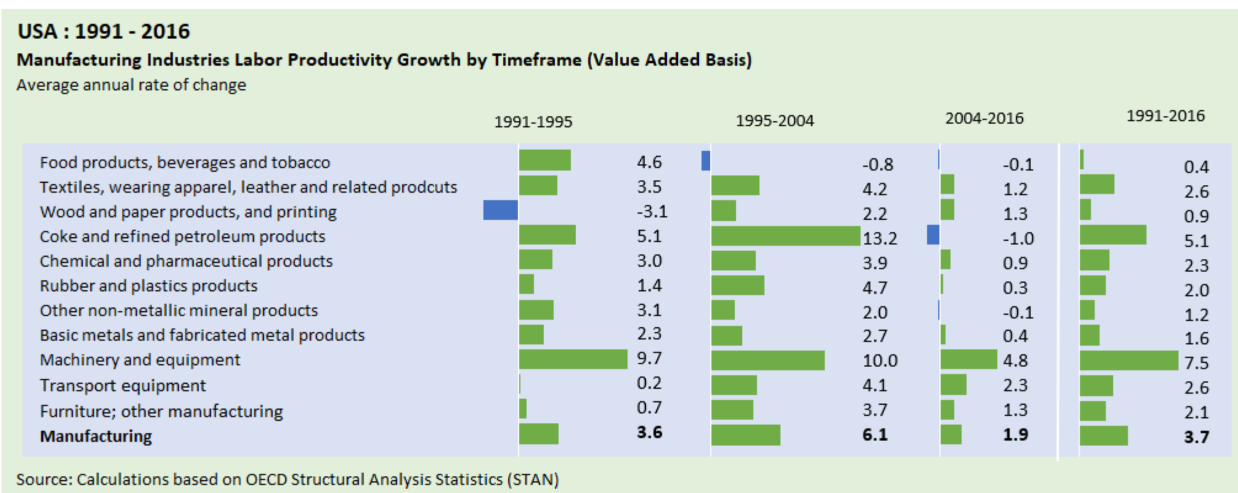
Looking only at the slow-growth period from 2004 to 2016, however, there is a somewhat different result. Since 2004, the contribution of capital in Germany has been only 0.1 percent a year. In Japan, capital added 0.3 percent a year to labor productivity growth. In the United States, capital added the most to labor productivity growth at 0.6 percent a year. We noted earlier that labor productivity growth was at a similar rate, close to one percent per year, in all three countries 2004-16 but this similarity came from very different decompositions between TFP contribution and capital contribution. In Germany, almost all the growth was from TFP, while in the US the contribution from TFP was the least at 0.5 percent a year. In the United States, the slowdown was more concentrated an inability to push forward the technology frontier, while Japan and Germany had weaker capital deepening.

The slowdown of productivity growth after 2004 widespread and easily visible in the industry data for all three countries. In Japan, there are only two industries, construction and real estate, that show faster productivity growth after 2004 and this is the case for both labor productivity and TFP. In Germany, the slowdown in TFP is very mild overall, and several industries—mining, construction (by a tiny amount), financial services, and professional services (a smaller TFP decline)—have stronger TFP growth after 2004. Community, social and personal services stay the same, while manufacturing's slowdown is modest. In the United States, the TFP slowdown is largest in agriculture and manufacturing. Mining, real estate, professional services, community, social and personal services all show somewhat faster growth after 2004, and construction has a slightly smaller rate of decline.

Manufacturing Productivity

There is better data and more industry detail available for the manufacturing sector than for service industries. Also, given how important the manufacturing sector is to the overall slowdown in productivity (despite its modest share of GDP), it is worth looking in detail at manufacturing industries. Figures 7 a, b, and c show the labor productivity growth rates for select manufacturing subindustries. The TFP growth figures are given in Appendix 2. The coke and refined petroleum products industry is missing from the Germany figure because separate STAN data is not available for Germany. The data for Germany ends in 2015, compared to 2016 for Japan and the United States. There is no STAN data for Japan prior to 1995.

Figures 7 a, b, and c. Manufacturing Labor Productivity Growth, US Japan and Germany



Japan : 1995 - 2016

Manufacturing Industries Labor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1995-2004	2004-2016	1995-2016
Food products, beverages and tobacco	-0.1	0.0	0.0
Textiles and wearing apparel	-0.5	0.3	-0.1
Paper and paper products	0.6	0.1	0.3
Coke and refined petroleum products	-0.3	-0.9	-0.6
Chemical and pharmaceutical products	2.5	1.5	1.9
Other non-metallic mineral products	2.7	-0.3	1.0
Basic metals and fabricated metal products	0.9	0.3	0.5
Machinery and equipment	7.2	5.5	6.3
Transport equipment	2.1	0.5	1.1
Manufacturing	**3.3**	**2.4**	**2.8**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Germany : 1991 - 2015

Manufacturing Industries Labor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2015	1991-2015
Food products, beverages and tobacco	-0.9	-0.5	1.7	0.4
Textiles and wearing apparel	5.8	3.4	0.9	2.6
Wood and paper products, and printing	2.3	2.7	2.3	2.5
Chemical and pharmaceutical products	8.1	4.7	0.9	3.5
Rubber and plastics product; other non-metallic mineral products	4.5	2.3	1.3	2.2
Basic metals and fabricated metal products	3.2	2.4	0.7	1.8
Machinery and equipment	3.9	3.6	1.4	2.6
Transport equipment	1.3	1.4	4.5	2.8
Furniture; other manufacturing	2.0	3.4	0.7	1.9
Manufacturing	**3.2**	**2.9**	**1.9**	**2.5**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

The data for Germany are very striking in that there is relatively steady growth across the sub-industries in manufacturing over the period from 1991 to 2015, although with a broad slowdown after 2004. Food products and transportation equipment are exceptions to this pattern, with much faster growth after 2004. Both in labor productivity, and TFP (in Appendix 2), it appears that German manufacturing companies are able to improve operations year by year across a broad range of industries. There are not periods of very rapid growth (as in the United Stated in the 90s) but improvement is generally continuous. The United States and Japan had faster growth than Germany over the full period, but it came more in fits and starts and has been markedly slow since 2004, especially in the United States. United States growth has been very strong in machinery and equipment (where computers and electronics are located in this data) but has seen little consistent growth in other manufacturing industries, and very slow growth since 2004. The story for Japan has been surprisingly similar, with consistently strong productivity growth in machinery and equipment and little growth elsewhere. Research by Jorgenson, Nomura and Samuels (2018) supports the finding of slow Japanese manufacturing productivity growth since 1995 and finds Japanese manufacturing productivity growth was much faster in earlier periods.

The data on industry growth rates reveal some patterns that can be helpful in identifying industries that might grow faster in the future. For example, utilities with negative TFP growth. We turn now to the additional information that can be learned from using productivity levels as well as growth rates. We will then try to pull together all the sources of information.

Problem Industries Identified Using Productivity Levels and Growth Rates

According to a simple catch-up growth model, the most rapid productivity growth should occur where the gap to the productivity frontier is greatest. If this is correct, it provides a way to diagnose industries with a productivity problem in cases where the level of productivity is below the frontier but where catch up is not occurring. Specifically, we will look at industries that were below the productivity level of the United States industry in 1994 but where the productivity growth rate 1995-2016 was slower than in the United States. Of course, we can also diagnose United States industries with a problem, where the productivity level was below either Japan or Germany but where the United States industry was growing more slowly. If we find a “problem” industry, we can then explore what the barriers are to its achieving frontier—level productivity. In some cases, there may be a natural barrier as we noted earlier in this paper. However, if the barrier to high productivity is the result of regulation, or problems in technology development, or lack of skills, or some other policy lever or constraint, then better future performance may be possible. The first step, therefore, is to identify lagging or problem industries.[5]

Specific Method Used. Using the results already presented for industry labor productivity growth rates we can calculate the rate of growth of each industry in Japan and each industry in

[5] The approach described here was used in the productivity comparison studies from the McKinsey Global Institute. The methods are described in Baily and Solow (2001).

Germany over the period 1995-2016 and compare it to the growth rate in the same industry in the United States. In other words, we calculate the growth rate differentials over the period since 1995. These differentials are plotted on the vertical axis of the charts below, and the zero line indicates the same growth rate in two comparison countries. A positive number indicates that the industry in either Japan or Germany is growing faster than the equivalent industry in the United States. A negative number indicates the industry in the United States is growing faster.

On the horizontal axis of the chart, we plot the natural logarithm of the ratio of the level of labor productivity in Japan or Germany to the level of labor productivity in the United States. If the levels of productivity are the same in two countries, then the ratio is unity and log value is zero—this is the vertical axis in the figure. Points to the right of the zero axis line show industries where labor productivity was higher in either Japan or Germany in 1994. Points to the left show industries where productivity was higher in the United States.

The horizontal and vertical axes divide the industries into four quadrants. The upper left quadrant is where the United States productivity level was higher but United States productivity growth has been slower. This case indicates that the industry in Japan or in Germany was behind the United States level of productivity but was catching up—that is, there was convergence to the United States frontier productivity level. The lower right quadrant is where the United States productivity level is lower than in either Germany or Japan but where the United States industry is catching up. Thus, both the upper left and the lower right quadrants are consistent with the convergence hypothesis, where the industry that was below the frontier level of productivity was also catching up to the frontier. An industry may be behind, but it is overcoming that gap. Table 1 below may help illustrate.

Table 1: Industry Productivity Growth Differentials against Productivity Levels

	US industry productivity level higher	**Japan/Germany industry productivity level higher**
Japan/Germany industry productivity growing faster	Japan/Germany converging to the US level *(convergence)*	US falling further behind Japan/Germany (*problem industries)*
US industry productivity growing faster	Japan/Germany falling further behind the US (*problem industries)*	US converging to Japan/Germany level *(convergence)*

The industries in the lower left quadrant or in the upper right quadrant do not fit the convergence model. These are industries that were below the most productive industry but were falling further behind. The lower left quadrant is for problem industries either in Japan or Germany. The upper right quadrant is for problem United States industries that were below level of productivity in either Japan or Germany but were also growing more slowly, falling further behind.

In order to make the comparisons of productivity levels, estimates of industry purchasing power parity (PPP) exchange rates are needed. These are available from the Gröningen Growth and Development Project (GGDC), which also partners with the Conference Board. They allow industry value-added measured in dollars in the United States to be compared to industry value-added measured in yen in Japan or in euros in Germany. These data also have PPP exchange rates for inputs. The comparison is made in one base year, which is 1997 for the GGDC PPPs, but by using growth rates of productivity over time, we are able to compare productivity levels in other years also. There are other possible estimates of PPP exchange rates, which we will discuss later.

Figure 8a shows the industry plots for all the broad industries in the STAN data base and then Figure 8b looks only at the manufacturing sub-industries. Industries in Japan are shown as red dots and industries in Germany as blue dots. The figures reveal that labor productivity in both Japan and Germany tends to be below the level of productivity in the United States (the points are to the left of the zero line). Some of the industries are in the upper quadrant, indicating they grew faster than the United States industry over the period 1995-2016 (they were converging), but many are in the lower quadrant, indicating they fell further behind US productivity.

Figure 8 a: Industry Productivity Growth Differentials against Productivity Levels Relative to the United States. Japan and Germany, broad industries, labor productivity.

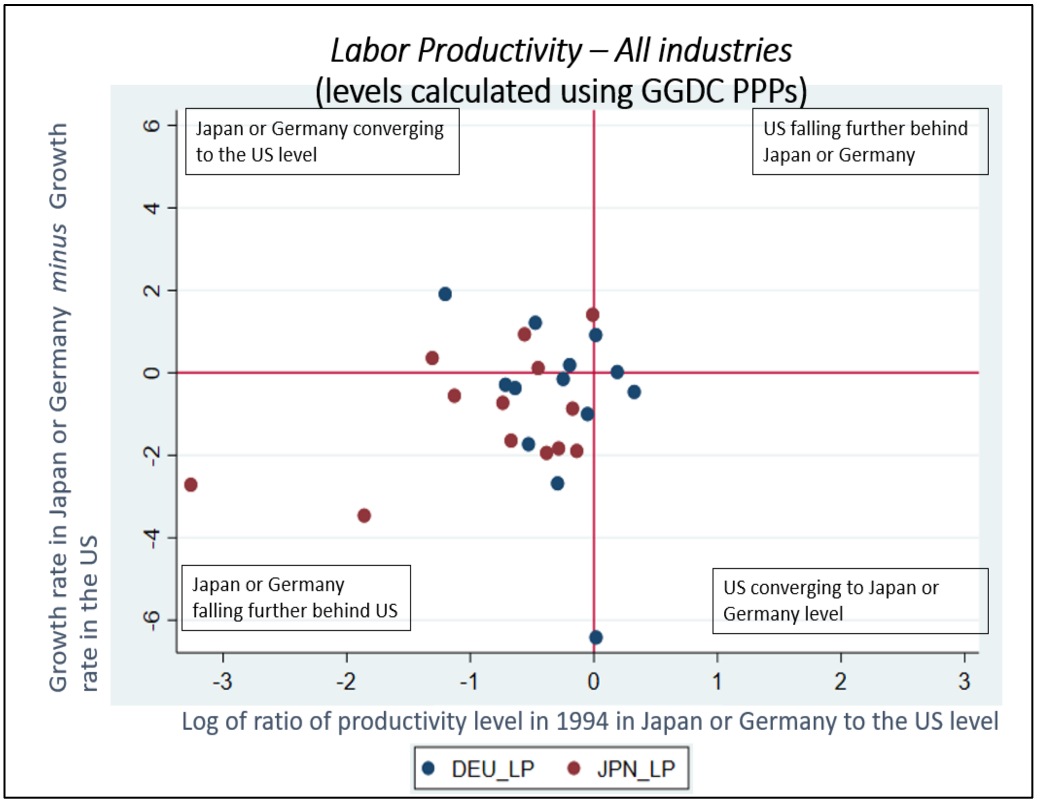
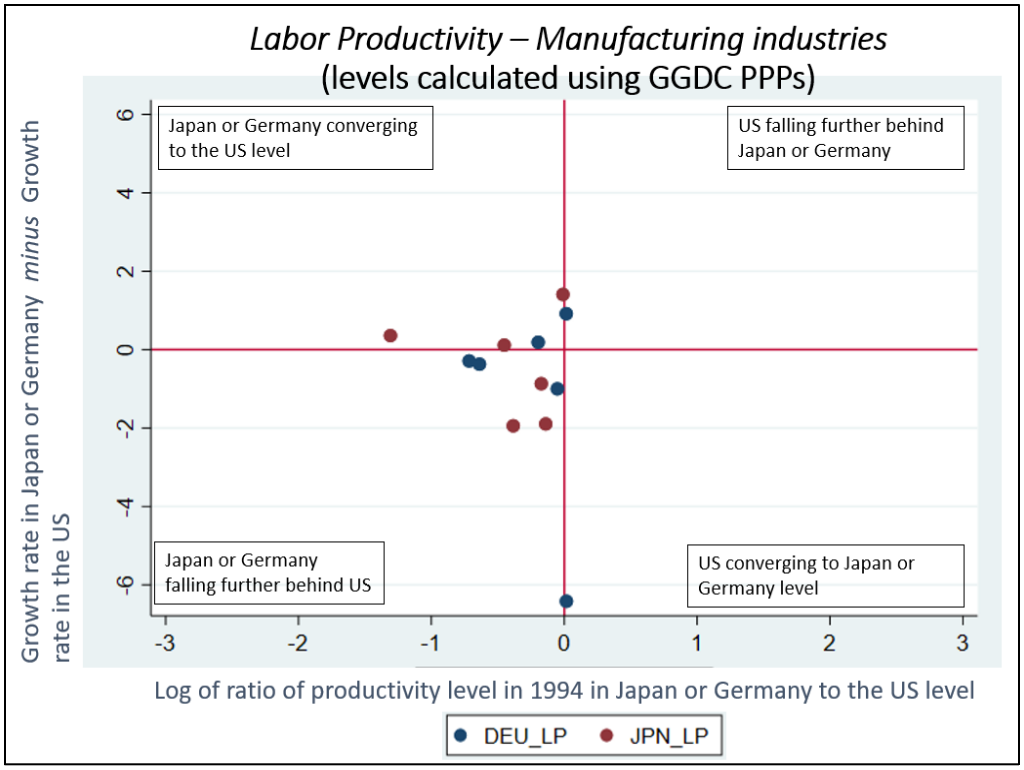


Figure 8 b: Industry Productivity Growth Differentials against Productivity Levels Relative to the United States. Japan and Germany, manufacturing sub-industries, labor productivity.



Looking at the manufacturing industries in Figure 8b reveals a pattern that also shows most industries at or below the United States level of labor productivity, although the industries for the most part are clustered near the vertical axis. The distribution of productivities by industry is closer to the productivity level of the United States for manufacturing than for service industries, a result that is to be expected given the importance of international trade and the strength of Japan and Germany in their manufacturing sectors. Products can move across borders more easily than services, forcing industries to converge to the productivity frontier in order to compete globally.

We have not included industry labels on these figures because it is very hard to make them legible, however the labels have been added in Appendix 3. The industries in Japan that may be problematic are agriculture, mining, real estate, trade, finance, and electrical machinery. The food products industry and construction may also be of concern because the levels of productivity were low in 1994 and they are only catching up to the United States slowly over the period 1995-2016, especially so for food products. The United States has no industries to the right of the vertical axis, but should be concerned about machinery, which grew more slowly than the industry in Japan and food products that grew more slowly than the industry in Germany. In both cases the United States industry started out at the same productivity level in 1994.

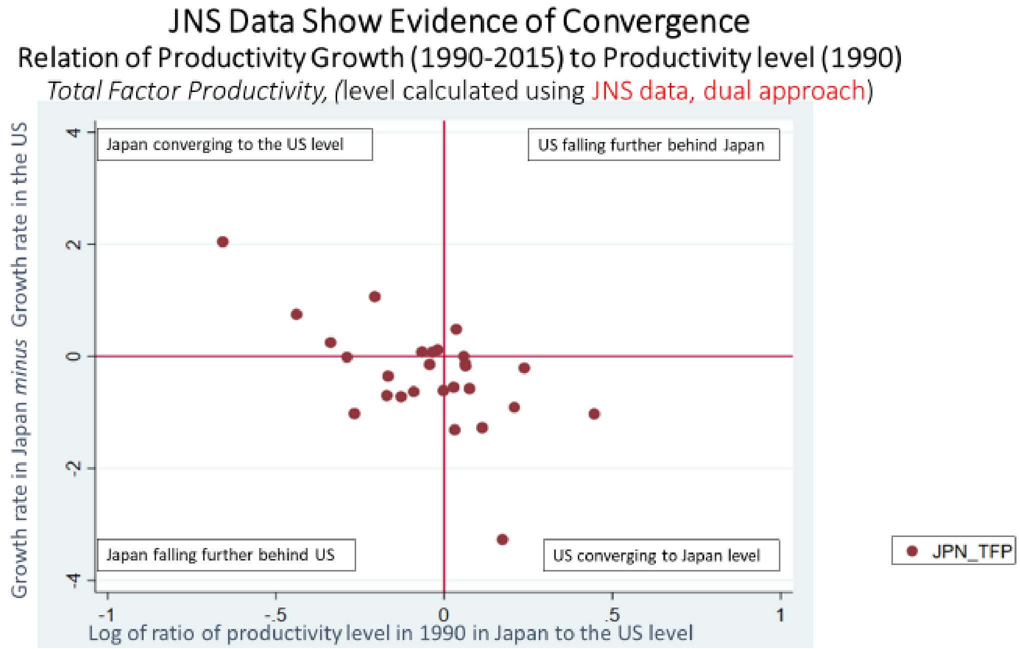
Because of the uncertainties involved in estimating PPP exchange rates for individual industries, we have looked at two alternative approaches to comparing productivity levels. The first is to use the average exchange rate over the period 1994-2016 for Japan/United States and Germany/United States. For manufacturing industries, where trade is more important, exchange rates provide a useful alternate measure. With average exchange rates we find that the clear productivity superiority of United States industries is reduced or eliminated. The Japanese industries that continue to be problematic are electrical machinery and, to a degree, food products. The United States has a problematic industry in machinery and is behind but catching up in basic metals and fabricated metal products, as well as transportation equipment. For Germany, the electrical and optical equipment industry stands out because its productivity growth rate was over 6 percentage points a year slower than the growth in the United States industry.

Productivity Level and Growth Results from Jorgenson, Nomura and Samuels (JNS)

JNS calculated their own productivity growth rates and levels for 36 industries in Japan using the price or dual approach to TFP estimation. Although their data are proprietary, they have generously made them available. Since their analysis is structured around TFP estimation we have plotted the comparable figure to those shown in Figures 8 a and b in terms of TFP, as shown in Figure 9. [6] The industry labels for this figure are shown in the Appendix.

[6] JNS calculate TFP from gross output adjusting for all inputs, capital, labor, materials and purchased services. This results in estimates of TFP growth that are smaller, scaled differently, than estimates from value added. That scaling difference does not impact the lessons to be learned from TFP performance.

Figure 9: Industry Productivity Growth Differentials against Productivity Levels, Japan Relative to the United States



Source: Calculations based on JNS data.
*Note that the scale on this chart is different from the charts on the previous slides.

Unlike the prior results, the JNS TFP data show strong evidence of convergence with a majority of the industries falling in the upper left quadrant or the lower right quadrant. The JNS figures for TFP show many industries where the US was behind Japan in 1990, all of them manufacturing sub-industries. All but two of these converged towards Japan over the period from 1990 to 2015. Despite the general pattern of convergence, there are six industries in Japan that were behind the US in 1990 and fell further behind subsequently. These include agriculture, furniture, machinery, water transport, and other transport and storage.

In addition, mining, apparel, printing, rail transport and finance and insurance started above the US in 1990 but fell below by 2015. A particular concern is that when TFP in Japan is higher than in the US in 1990, there is, on average, a decline in TFP over the subsequent period, 1990-2015. US industries in the lower right quadrant in the figure are catching up to Japan but this is

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In their work, JNS provide productivity data back to 1955, however, the focus of this report is on more recent data and we will look particularly at the results from 1990 to 2015.

happening in part because of weak Japanese performance (declining TFP) in the industries that had been productivity leaders in 1990.

The computer industry has not been included in Figure 9 because it is a huge outlier in terms of growth in both countries. The level of TFP in this industry in Japan was well above the US level in 1990 (ratio of about 1.4). In subsequent years, growth was rapid in both countries, although faster in the United States (6 percent compared to 5 percent in Japan) and the TFP levels in the two countries end up about the same by 2015. Based on TFP growth, this industry was successful in both economies but there remains concern about the performance of the high-tech or advanced manufacturing sector in Japan and about R&D performance (see the companion paper by Dany Bahar and the discussion of the McKinsey study below).

We also used the JNS data to calculate labor productivity for their industries, based on value added per hour worked. There is less convergence in the labor productivity estimates, which is surprising since capital accumulation has been seen in the literature as an important way in which convergence occurs to equalize labor productivity levels as countries develop. The lack of convergence in labor productivity may reflect weakness in capital accumulation in Japan 1990-2015.

It can get confusing to present too many numbers, so summary of the labor productivity results is shown below. The data are given in Appendix 4.

Summary of JNS Labor Productivity Results

- *Behind or fell behind US*: Agriculture, mining, construction, food, machinery, apparel and leather, textiles, furniture, printing, petroleum, other transportation equipment, metal products, computer and electronic products, miscellaneous manufacturing, wholesale and retail trade, finance insurance, real estate, electricity and gas.
- *Caught up to and exceeded US*: wood products.
- *Matched US*: stone clay class, autos[7], paper, chemical products.

[7] The productivity in the auto industry was well above US level in 1990. As Japanese companies invested in the US market they brought their productivity levels with them and forced the US makers to match performance. This is an industry where the US was behind Japan but caught up.

- *Stayed or moved ahead of US*: primary metals, other electrical machinery.
- *Catching up to US, but progress stalled post-2011*: communications.

As with the TFP data, the labor productivity data also show that Japan's productivity exceeded that in the United States in several industries, especially going back to 1990.

The McKinsey Global Institute Studies of Japan

Starting in the early 1990s, the McKinsey Global Institute conducted a series of productivity comparisons among advanced and emerging economies. Comparisons were made with Japan, Germany, France, the UK, the Netherlands, Sweden and others. These comparisons were restricted to a limited number of well-defined industries, and much of the work effort went into estimating PPP exchange rates for these industries, or else finding a quantitative measure of output—for example, quality-adjusted tons of steel. A main result that emerged from the comparisons with Japan was that the most productive Japanese industries were ahead of the United States, notably in automobiles, machine tools and steel. These were industries that had been at the center of the Japanese economic revival of the 1950s and 60s and by the 1970s Japanese companies, such as Toyota, were conquering global markets, including the United States. Despite these successful industries, average labor productivity in Japan was found to be well below that in the United States with both service industries and protected manufacturing industries at a productivity disadvantage.[8] The idea emerged of Japan as a dual economy. Part of the economy was highly productive and competitive with global industries while part was much less productive and was often subject to restrictive regulation that either prevented an industry from evolving productively or that limited competition, allowing unproductive firms to survive. In relation to the earlier discussion, it was found that many Japanese industries, especially in manufacturing, had caught up to best practice and were establishing a new more productive frontier in several industries, but many other industries had not caught up, especially in services and protected domestic manufacturing.

[8] The studies of productivity can all be found on the McKinsey Global Institute website at https://www.mckinsey.com/mgi/overview. The early studies were described in Baily (1993) and Baily and Gersbach (1995).

In March 2015, the McKinsey Global Institute, in collaboration with the Tokyo office of McKinsey & Company, published a new report on productivity in Japan (Desvaux et al. 2015). The 2015 study did not try to estimate its own PPPs but used PPPs from the World Bank as well as exchange rates for manufacturing industries. Estimates of both labor productivity and capital productivity (output per unit of capital) were made and it was reported that all the industries examined were at a labor productivity disadvantage relative to the United States in 2011, see Exhibit E1 of the report.[9] The report had estimates for 2000, 2005 and 2011 and found that some industries, such as health and social work, construction, utilities and hotels and restaurants were catching up in labor productivity, while the rest had fallen further behind since 2000. The McKinsey study looked in more detail at three specific industries where they found productivity gaps, including advanced manufacturing, retail and health care. The McKinsey consultants in Tokyo worked with Japanese companies in these industries and report the concerns they have about falling behind best practice performance.

Putting the Diverse Results Together

One the main priorities of this research was to identify industries in Japan that have a productivity concern and start to think about what might be done to improve performance. In the design of this project, we judged that combining data on industry productivity growth rates with data on productivity levels would provide the most compelling way to identify problem industries in all three economies, which would then lead the way to further research in Japan, Germany and the United States. Not surprisingly, as the research results have emerged, we found the results differ depending on the data used. Despite these differences, there are messages that can guide the search for industries with productivity growth potential.

In this discussion we will point to potential reasons for the observed productivity gaps. We stress that as United States-based economists we do not have hands-on knowledge of the workings of the Japanese economy nor do we have rigorous enough empirical evidence to pass the test of econometricians.

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[9] The report found capital productivity in Japan was lower than in the United States except for the real estate sector in 2011.

Economy-wide factors that could improve productivity performance in Japan

First, as we have shown in the companion section of our overall report, there is a concern in Japan about the effectiveness of the research and development (R&D) strategy of business and about the incentives that are created by R&D policies in Japan.

Second, we have found evidence both in the aggregate data and in the industry data suggesting that a reason convergence has not been completed in Japan is because of weakness in investment and capital deepening. There are different possible reasons for this. China has become a formidable competitor in many manufacturing industries, which may have eroded Japan's share of the global market. The financial crisis of the late 1980s left Japanese financial institutions weakened and subsequent financial crises may have perpetuated the problems, leading to efforts to keep companies alive that should have been allowed to fail (zombie firms). Lending to keep weak companies alive may have reduced lending to stronger companies or newly emerging companies. We do not know the explanation for the weakness in capital spending in Japan, but judge it is an important issue. Are there barriers to investment in successful and growing companies? Would investment incentives help the problem?

Industry Specific Problems

1. *Wholesale and retail trade were important to the growth slowdown*. All three countries experienced strong productivity growth in wholesale and retail trade from 1995 to 2004, growth that slowed in the subsequent period. The United States growth was the most rapid and slowed by the largest amount. Japan had the fastest growth from 1991-95 and slowed to zero TFP growth by the last period. The level of productivity is well below that the United States. In Japan, this is an industry that has been examined in the past and where there are concerns about the protectionism shown to small, low-productivity establishments. The large-scale retail store law was repealed in 1990 but its effect continues. Small convenience stores still accounted for 52 percent of retail sales and 65 percent of employment in 2012 in Japan (Desvaux et al. 2015, Exhibit 18). An IMF study by Colacelli and Hong (2019) finds a significant drag on Japanese productivity from small and medium-sized enterprises.

2. *Advanced manufacturing*: includes electrical and optical equipment, machinery and transportation equipment. There are strong Japanese companies in this sector, such as the auto companies, that continue to prosper globally. However, many companies in these industries have seen their market share erode in the face of global competition (Desvaux et al. 2015, Exhibit 15). In the computer, electronics and optical equipment sectors, Japan has not been able to keep pace with Silicon Valley in innovation and design, while much of the manufacturing is now taking place in China or other countries in Asia. China still has a technology gap but is pouring resources into R&D in advanced manufacturing industries. The United States has a strong aerospace sector that benefits from financial support from the United States government. As we have discussed in the chapter of this report on R&D, there is concern about innovative performance in Japan.
3. *Utilities*. What is the matter with utilities? Both Japan and the United States industries have seen negative TFP and labor productivity growth over periods of years. The level of productivity in Japan is lower than in the United States, much lower in some estimates. Problems associated with regulation and the shifts in fuel sources may provide some explanation for the difficulties in this sector. Japan has moved away from nuclear generation but is also trying to reduce fossil fuel emissions. Over time, the development of wind and solar technologies will change the economics of this industry, although it is not clear if these technologies will increase or decrease costs.
4. *The food processing industry* is a large sector within manufacturing linked to the agricultural sector that does not face global competition. It is an industry that is impacted by local regulation.[10] There is concern that too many small companies remain in operation weighing down average productivity.

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[10] Comparing productivity across countries is difficult because of different consumer tastes. The United States industry caters to the mass market while Japan has a greater focus on quality. The JNS results indicate little productivity gap to the United States. Nevertheless, it is important that competition within Japan be allowed to flourish and that Japanese consumers be given access to imported food products if they choose to buy them with regulations applied uniformly and with transparency.

5. *Agriculture.* There is consensus that this is an industry with a relative productivity problem. The natural economic outcome for this industry would be for it to reduce its size until the point where it becomes competitive. Regulatory and trade barriers currently prevent this from happening. There may be a desire to maintain greenspace in Japan, but this can be achieved through national parks rather than through unproductive farms. There may be a decision made to support agriculture for strategic or geopolitical reasons. If so, the costs and benefits of such a policy should be carefully evaluated and there may be better ways to safeguard Japan's food independence than through agricultural subsidies.[11]
6. *Mining* is a small industry but one that provides a drag on productivity. As with agriculture, strategic reserves of fuel and materials may be a cheaper alternative to maintaining an uncompetitive industry. The mix of products in this industry in Japan may be one reason for its relatively low productivity performance.
7. *Construction* is an industry that has severe productivity problems in both the United States and Japan. Measurement of productivity is difficult in this industry and, in addition, regulation and labor rules can make it difficult to innovate and achieve strong performance.

Lagging Sectors in the United States. Given how slow productivity growth has been in the United States in recent years, there is no place for complacency among US businesses or policymakers. All countries face the challenge of sustaining economic growth at a time of increasing concern about climate change and the impact of fossil fuels. It becomes even more important to find ways to improve the efficiency of production if we also need to make a major shift towards new energy sources. Are there any lessons for United States growth from our comparison of the three largest advanced economies?

Given the size and importance of the utilities sector and its dismal productivity performance in both Japan and United States, it would be helpful to examine this sector to identify the reasons for this productivity failure. This is especially true given its role in emissions control and climate

[11] We note that both the United States and the European Union provide subsidies or other support to agriculture.

change. Paradoxically, one reason for this industry's problems may be that the technology is changing so rapidly. The electricity generation industry has moved from coal to natural gas (with US regulators first pushing the industry to abandon coal and now encouraging the use of coal). The rapid advance of wind and solar power is necessitating a new shift away from fossil fuels.

Germany lacks a high-tech sector to rival Silicon Valley, which helps explain why its aggregate level of productivity has dropped below the United States level. However, the data on manufacturing show Germany making much steadier progress than the United States and growing faster since 2004. This study does not tell us why this is the case, but one hypothesis worth exploring is that Germany invests much more in workforce training. The United States invests heavily in college education and has many top universities but spends very little on vocational education. Japanese companies that came to the United States in the 1970s and 80s found they needed to invest heavily in worker training and the same has been true for German companies such as BMW, Mercedes and Volkswagen when they invested heavily in the 1990s and 2000s. United States companies can surely learn from Japanese and German companies about the importance of worker training to achieving high-productivity workplaces, especially in manufacturing.

Conclusion

The Japanese economy grew very strongly and made substantial progress in catching up to best practice levels of productivity, but in the 1990s that relative progress stalled out and GDP per hour worked fell further behind the levels achieved in both Germany and the United States. This report is intended to provide new information about the industry patterns of productivity, looking at both growth rates and at alternative estimates of productivity levels.

The information provided here provides a way to identify productivity problem areas, which can then lead to deeper analysis of the sources of the difficulties. In the United States, Robert Gordon has argued that it will not be possible to return to an era of rapid growth. However, in Japan the immediate challenge is to complete the catch-up of productivity, catchup growth that was so successful in an earlier period.

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Appendix 1. TFP Growth in Broad Industries

USA : 1991 - 2016

Industry Total Factor Productivity Growth by Timeframe (Value-Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016
Agriculture, forestry and fishing	-2.7	5.1	1.6	2.2
Mining and quarrying	5.8	-0.4	2.6	2.0
Manufacturing	2.1	4.4	0.7	2.3
Utilities	0.5	-0.8	-1.2	-0.8
Construction	-0.8	-2.0	-1.7	-1.6
Wholesale and retail trade	1.5	4.0	0.6	2.0
Transportation and storage	0.0	1.3	-0.2	0.4
Information and communication	0.6	2.7	2.9	2.4
Financial and insurance activities	-0.1	2.5	0.8	1.3
Real estate	0.7	-0.2	1.3	0.7
Professional, Scientific and Administrative services	-1.2	0.1	0.3	0.0
Community, Social and Personal services	-0.4	-0.3	0.0	-0.1
Private Business Sector	**1.1**	**2.6**	**0.5**	**1.4**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Japan : 1991 - 2016

Industry Total Factor Productivity Growth by Timeframe (Value-Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016*
Agriculture, forestry and fishing	-	0.5	1.6	1.1*
Mining and quarrying	-8.8	3.0	-7.6	-4.0
Manufacturing	0.1	2.0	1.8	1.6
Utilities	-1.6	0.8	-3.3	-1.6
Construction	-	-1.2	0.9	0.0*
Wholesale and retail trade	4.2	1.7	0.0	1.3
Transportation and storage	0.6	-0.5	-0.8	-0.5
Information and communication	5.0	4.3	0.3	2.5
Financial and insurance activities	-1.3	-2.2	0.3	-0.9
Real estate	-	0.2	1.6	1.0*
Professional, Scientific and Administrative services	1.1	2.7	1.4	1.8
Community, Social and Personal services	-1.4	-0.5	-0.3	-0.6
Private Business Sector	**0.2**	**1.2**	**0.7**	**0.8**

*1995-2016 for starred industries

Source: Calculations based on OECD Structural Analysis Statistics (STAN); Numbers before 1994 extrapolated using JIP data

Germany : 1991 - 2016

Industry Total Factor Productivity Growth by Timeframe (Value-Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016
Agriculture, forestry and fishing	-8.9	5.2	-2.4	-0.7
Mining and quarrying	4.7	-0.8	1.4	1.1
Manufacturing	1.4	2.5	1.9	2.0
Utilities	-1.5	1.7	1.2	1.0
Construction	-1.8	0.2	0.3	-0.1
Wholesale and retail trade	-0.7	2.4	1.4	1.4
Transportation and storage	2.3	2.2	0.2	1.3
Information and communication	3.8	5.5	3.6	4.3
Financial and insurance activities	-0.1	-2.5	1.1	-0.4
Real estate	3.3	1.1	0.3	1.1
Professional, Scientific and Administrative services	0.9	-2.6	-1.1	-1.3
Community, Social and Personal services	1.6	0.4	0.4	0.6
Private Business Sector	**0.2**	**1.3**	**1.1**	**1.0**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Appendix 2. TFP Growth in Manufacturing Industries

USA : 1991 - 2016

Manufacturing Industries Total Factor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1991-1995	1995-2004	2004-2016	1991-2016
Food products, beverages and tobacco	4.3	-1.5	-0.7	-0.2
Textiles, wearing apparel, leather and related prodcuts	2.9	2.7	0.8	1.8
Wood and paper products, and printing	-2.7	1.5	0.6	0.4
Coke and refined petroleum products	3.0	11.8	-3.5	3.0
Chemical and pharmaceutical products	0.4	0.5	-2.3	-0.9
Rubber and plastics products	1.6	3.1	-0.2	1.3
Other non-metallic mineral products	4.2	1.5	-0.8	0.8
Basic metals and fabricated metal products	2.7	2.3	0.1	1.3
Machinery and equipment	8.8	7.8	4.2	6.3
Transport equipment	-0.6	2.6	1.9	1.8
Furniture; other manufacturing	NA	NA	0.7	NA
Manufacturing	**3.1**	**4.4**	**0.7**	**2.4**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Japan : 1995 - 2016

Manufacturing Industries Total Factor Productivity Growth by Timeframe (Value Added Basis)

Average annual rate of change

	1995-2004	2004-2016	1995-2016
Food products, beverages and tobacco	-0.8	-0.4	-0.6
Textiles and wearing apparel	-1.3	0.1	-0.5
Paper and paper products	-0.3	-0.3	-0.3
Coke and refined petroleum products	-3.4	1.2	-0.7
Chemical and pharmaceutical products	0.6	1.2	0.9
Other non-metallic mineral products	1.5	-0.4	0.4
Basic metals and fabricated metal products	0.6	0.4	0.5
Machinery and equipment	5.4	4.5	4.9
Transport equipment	1.6	0.4	1.0
Manufacturing	**2.0**	**1.8**	**1.9**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Germany : 1991 - 2015

Manufacturing Industries Total Factor Productivity Growth by Timeframe (Value Added Basis)

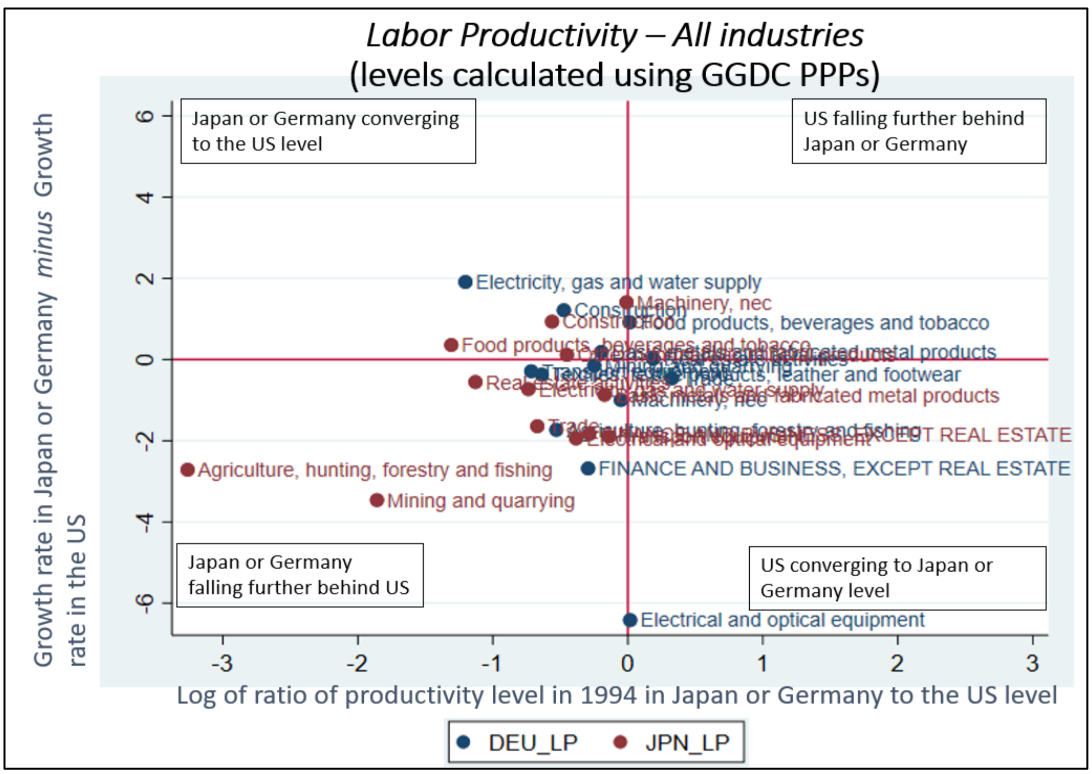
Average annual rate of change

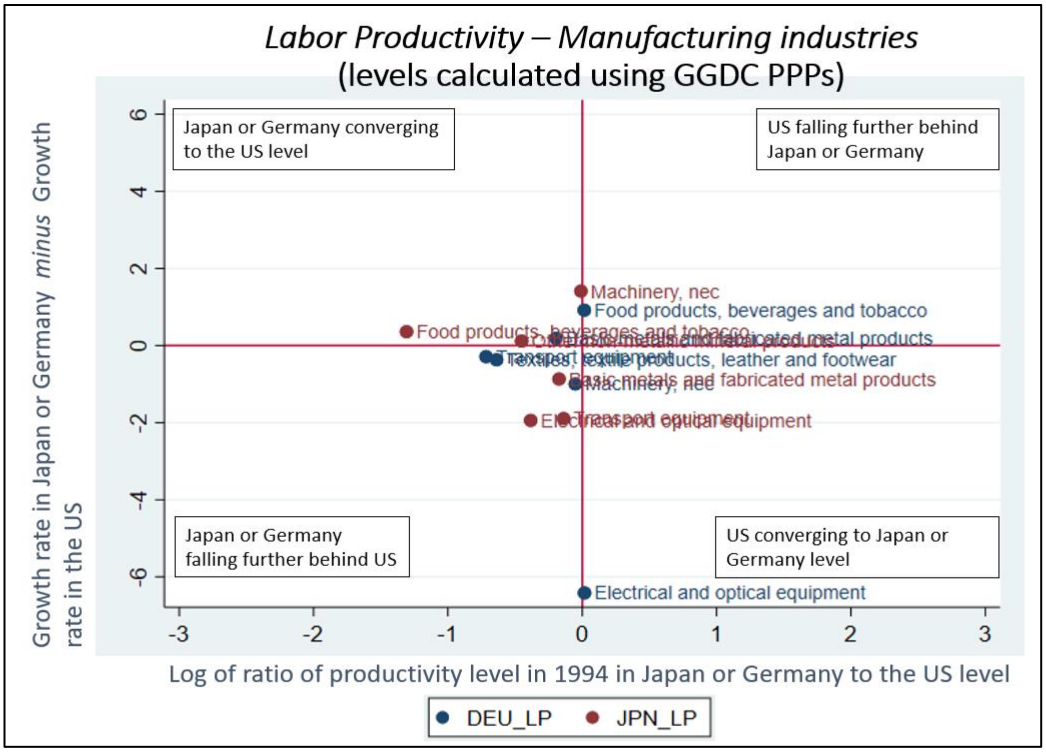
	1991-1995	1995-2004	2004-2015	1991-2015
Food products, beverages and tobacco	-2.1	0.2	1.9	0.6
Textiles and wearing apparel	3.2	3.2	1.3	2.3
Wood and paper products, and printing	1.5	2.1	2.7	2.3
Chemical and pharmaceutical products	5.1	2.9	1.2	2.5
Rubber and plastics product; other non-metallic mineral products	3.0	2.1	1.7	2.1
Basic metals and fabricated metal products	2.5	2.2	0.9	1.7
Machinery and equipment	1.6	3.3	1.5	2.2
Transport equipment	-0.6	0.7	3.8	1.9
Furniture; other manufacturing	1.2	3.3	0.6	1.7
Manufacturing	**1.4**	**2.5**	**1.9**	**2.0**

Source: Calculations based on OECD Structural Analysis Statistics (STAN)

Appendix 3

Labor productivity or TFP growth rates and levels with industry labels

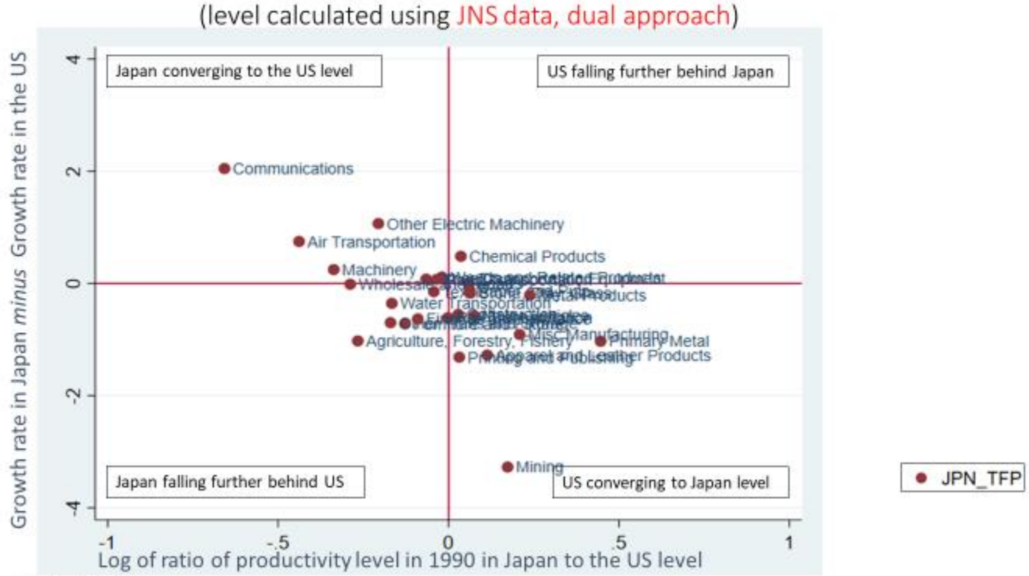




Relation of Productivity Growth (1990-2015) to Productivity level (1990)

Total Factor Productivity

(level calculated using JNS data, dual approach)



Source: Calculations based on JNS data.

*Note that the scale on this chart is different from the charts on the previous slides.