Lessons from a Career in Productivity Research: Some Answers, A Glimpse of the Future, and Much Left to Learn

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Abstract

This study presents lessons learned from a career in productivity research. It examines the extent to which the key empirical questions about productivity have been answered. Aggregate and industry growth data are reviewed and show how a few industries contribute a lot to overall growth; notable is the large contribution of high-tech manufacturing to U.S. TFP growth (also the case for Japan). There is an extended summary of the lessons learned from cross-country comparisons of the levels of productivity in different industries using business economics information. Strong competitive intensity is positive for productivity, while regulations and trade restrictions are negative. The article concludes with an optimistic note on the productivity impact of generative AI.

Productivity growth over many decades has transformed the United States, Canada, Europe, and Japan into wealthy countries. The progress made since the start of the industrial revolution has been a miracle, allowing most people in these countries to live comfortably and have a range of economic opportunities. Rising productivity is not the only factor, but it is the most important factor, improving living standards and lifting people out of poverty.

The world economy is changing. Is productivity still as important? There is well-justified concern about global warming and the need to reduce emissions. Further, economy-wide productivity increases have not contributed proportionately to workers' wages, so that there is dissatisfaction about economic performance.[2] This is a particular problem in the United States, where automation and trade have elimi-

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2 See Symposium on the Decoupling of Productivity and Pay in the United States, the United Kingdom and Canada in the Fall 2021 issue of the International Productivity Monitor (Sharpe and van Ark, 2021).

nated many of the jobs that used to provide middle-class incomes but these same forces are also at work in other advanced economies.

Despite these concerns, productivity remains very important. Meeting the challenge of climate change will mean heavy investments to switch over to non-polluting energy sources, replace the current stock of vehicles, and insulate buildings. Research and development funds are being used (correctly) to find ways to reduce emissions and many of the most talented people in the world are focused on climate change rather than on how to produce more output. Productivity growth has been slow in the advanced economies in recent years and the focus on climate change could provide a further drag on traditional measures of growth.[3] It remains just as important today to use resources as efficiently and productively as possible, subject to meeting climate goals. Moreover, even though increases in productivity have not translated one-for-one into wage increases for all workers, it is still the case that faster productivity growth means faster wage growth on average, and it makes more resources available to help those with low incomes.

This article describes lessons learned from a career of studying productivity. I have had the opportunity to work with a range of talented people coming from different backgrounds and countries. Some of this work has been in the academic tradition, published in journals or by Brookings, and some has come from a series of productivity studies carried out by the McKinsey Global Institute (MGI), the think-tank of McKinsey Company.

These two approaches to research have complemented each other. Academic studies use data that can be replicated by others and that build on the work of the many giants of the field. The disadvantage of academic studies is that the authors generally lack detailed knowledge of how companies and industries operate. The MGI studies, by contrast, included senior experts that had worked with firms and industries for many years. A disadvantage of the business research is that these studies cannot be replicated, except at great cost. To add to the economic expertise of these projects, however, a team of academic advisors was set up, with Nobel prize winner Robert M. Solow serving as the chair of the advisory committee for about a decade. I worked extensively on many of these studies.

The next section reviews the key questions productivity research has tried to answer, together with some summary facts about US and global growth. The paper then examines the contributions of each industry's TFP growth to total US business sector TFP growth. Lessons from the studies led by the McKinsey Global Institute are then presented, including the role of physical capital, human capital, and technology and innovation. The paper then describes the overall conclusions of these studies, particularly the impor-

3 There is a case for taking account of changes in the environment as part of measuring productivity. If that is done, investments to improve the environment would contribute to measured productivity. That is not done in this article where productivity is measured using traditionally measured output, for example in the productivity calculations made by the US Bureau of Labor Statistics.

tance of competitive intensity to labor productivity differences across countries. The next section summarizes productivity lessons from work on US establishment data, notably the relationship between declining dynamism and the slowdown in US productivity growth. There is then a review of the extent to which research has provided answers to the questions posed at the beginning of the paper. Research has contributed to a much deeper understanding of both productivity growth (labor and TFP) and the reasons for cross-country differences, but much remains to be learned. There is then an optimistic look at the likely contributions to future productivity growth coming from the rapid development of large language models and related software. There is a brief conclusion.

A caveat is in order. This review of lessons learned is oriented to my own interests and the studies I have been involved with. There is much excellent research not covered here.

The Questions Productivity Research has Tried to Answer

In 1957, Robert Solow found that about 80 per cent of the growth in labour productivity historically came not from increases in capital per worker but from a residual factor that is now called total factor productivity (TFP) and is often associated with technical change or technological progress.[4] Much subsequent research on productivity attempted to better understand this surprising finding and figure out what was behind the large growth residual. Solow explored models where technology is embodied in capital goods—vintage capital models. These capture important insights into the economy, highlighting the productivity advantage of operating with the most advanced machinery. However, even in these models, it remains the case that the pace of technological progress is the most important driver of long run growth. If technological progress slows, investment runs into diminishing returns because new vintages of capital do not generate much productivity advantage over prior vintages, and investment becomes less profitable for businesses. Rapid technological change is the most important driver of strong investment.

Work by Dale Jorgenson of Harvard and by Edward Denison of Brookings differed in important ways and generated disagreement, but they shared the common goal of whittling down the TFP residual.[5] They explored how the flow of capital services into production can differ from the stock of capital; how education and experience impact the productivity of the workforce; how R&D can contribute to growth; and the impact of economies of scale and regulation. Jorgenson expanded on the neoclassical growth model, and his productivity framework is now used worldwide.

Jorgenson and Denison did succeed in

4 The concept of total factor productivity was developed by Jan Tinbergen (1942). The theory of growth was developed by Solow (1956) and Swan (1956). Solow (1957) estimated the contribution of capital to growth.

5 Jorgenson's research is summarized on his Harvard University page (Jorgenson, 2022). Denison's research is described in Kendrick (1993). See also Romer (1986), who argued for understanding the sources of the TFP residual and how it was affected by economic factors.

whittling down the TFP residual, notably in identifying the contribution of human capital and the role of information and communications capital (ICT), but there remains to this day a substantial puzzle to understand the nature and determinants of the TFP growth that has been the main source of the rapid labour productivity growth that characterized the U.S. and other advanced economies in the postwar period. Understanding the determinants of the growth in TFP and the reasons for TFP differences across countries remains an important question and puzzle.

A sharp slowdown in productivity growth occurred in 1973-4 that had substantial consequences for living standards and for economic policy. The slowdown in growth altered the TFP puzzle. The decline in productivity growth was associated with a large decline in TFP growth and so the unexplained productivity residual became much smaller. Capital accumulation also slowed around the same time. Why did growth slow down sharply in the United States in the early 1970s, a slowdown that also took place in the other advanced economies?

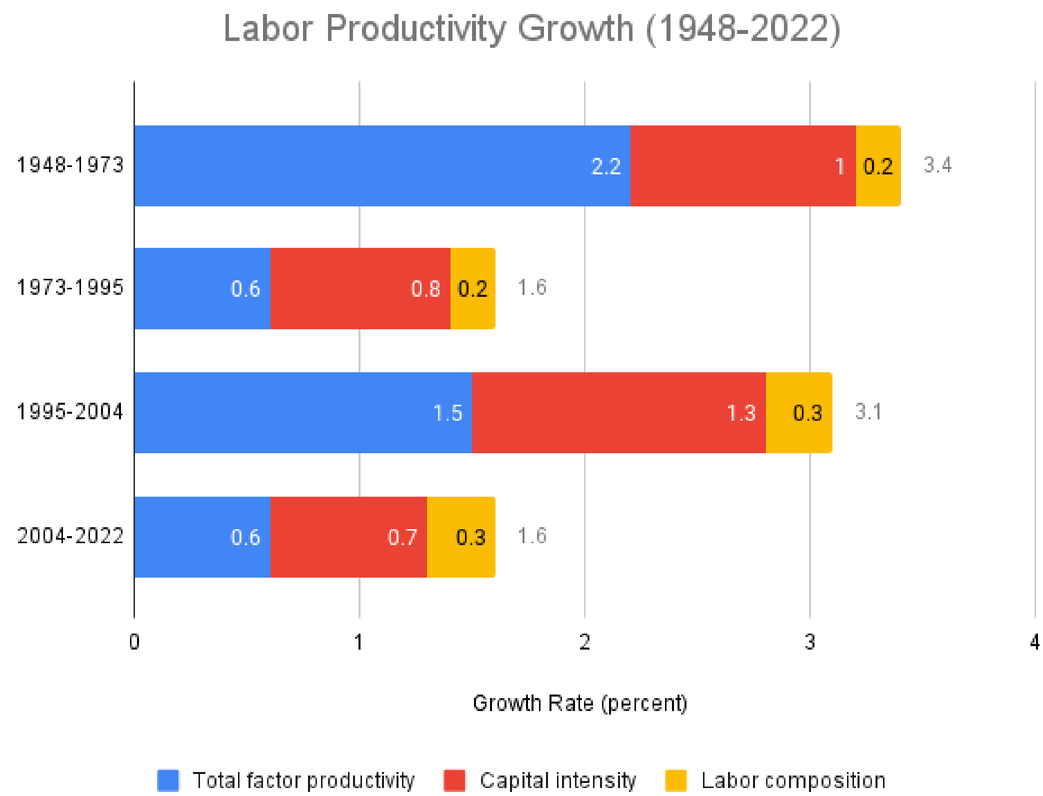
An especially puzzling feature of the slowdown in productivity growth in the early 1970s is that the drop in the speed of growth was quite abrupt. If it had been the case that TFP growth had gradually shown signs of decline over an extended period of years, it would have been natural to attribute this slowdown to a gradual exhaustion of technological opportunities. If one envisages technological progress as a process of selecting new business models or new technologies from a pool of possibilities that nature has provided to us, then it is natural to think that it might become gradually harder and harder to find new ways to increase productivity. The relentless march of growth in the period from 1950 to 1970, in this analogy, resulted in diminishing returns to the process of drawing from the limited pool of new technologies and ideas. However, the nature of the slowdown that took place in the early 1970s does not fit very well with this view of a gradual decline. The sharp drop in growth is an important feature of economic history. However, it probably is correct that the innovations that increase productivity have become harder to find.[6]

Just as economists and policymakers were adjusting to an era of much slower growth, productivity growth in the United States abruptly picked up again for almost a decade before slowing once again, leading to another growth puzzle. Why did productivity growth revive in the United States 1995-2004 and then slow again after that? There is a consensus that this was the result of the surge in investment in computers and other technology, together with the improvements in business systems that this facilitated.

Chart 1, using data from the Bureau of Labor Statistics (BLS), illustrates the different productivity periods since 1948, with estimates shown of the overall rate of labour productivity growth in the nonfarm

6 The editors of this journal commented that the oil price shock and the period of recession and rapid inflation that followed explain the abrupt productivity growth decline. My own view is that the abrupt slowdown remains a puzzle.

Chart 1: U.S. Labour Productivity Growth in the U.S. Non-Farm Business Sector in Selected Periods, 1948-2022



Source: Bureau of Labor Statistics

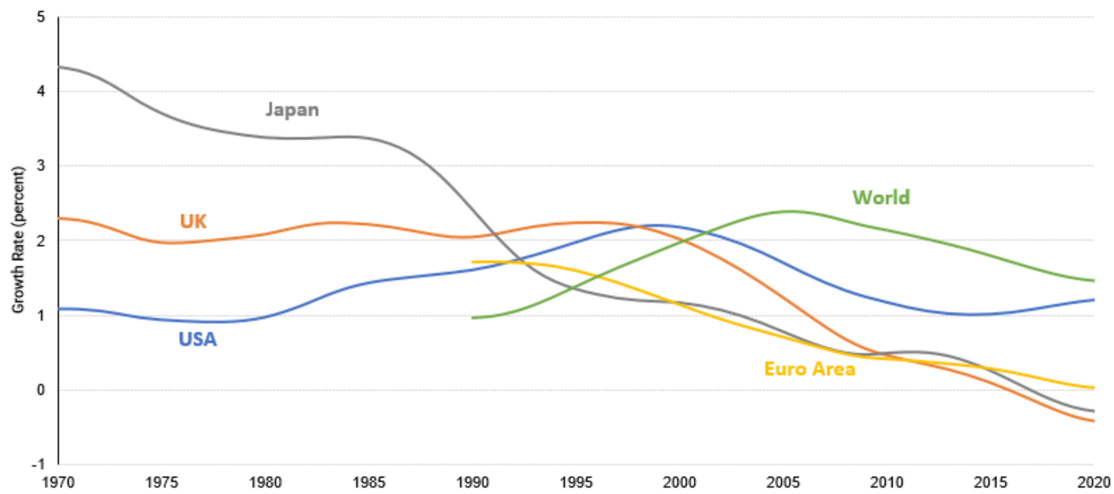
business sector by period and the contributions to that growth coming from TFP growth, capital intensity, and labour composition.[7]

The chart shows:

- The slowdown in labour productivity growth that occurred around 1973 was driven by a big drop in the TFP residual, from 2.2 per cent a year to 0.6 per cent a year.
- The contribution of labour composition remains roughly constant over the entire period. It is a consistent contributor but not large and does not explain variations in period-to-period growth.
- The contribution of capital to labour productivity growth tends to rise and fall in line with the rise and fall in TFP growth. However, the period 1995-2004 stands out as one with a very large capital intensity contribution. This was when computer prices were falling rapidly and investment in computers was booming. The estimated increase in real (quality-

7 This labour composition in the BLS estimate of the contribution of human capital improvements. Chart 1 covers non-farm business while Charts 2 and 3 cover all of GDP and Chart 4 includes the total business sector agriculture. Apologies to the reader for my lack of consistency

Chart 2: Labour Productivity Growth Per Person Employed



Source: The Conference Board Total Economy Database (adjusted version) 2021

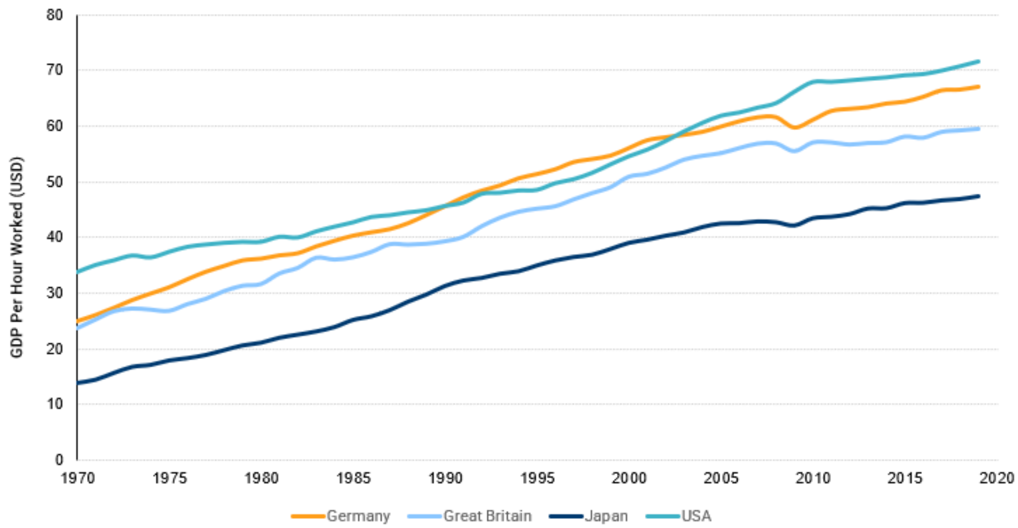
adjusted) capital was very large.

The United States is far from the only economy that has experienced a slowdown in labour productivity growth. In the 1950s, the U.S. economy had a much higher level of productivity than Japan and Europe. Of course, many of these economies had suffered severe damage during the Second World War. In the postwar period Europe and Japan grew more rapidly than did the United States, closing the productivity gap. Starting around the 1970s, however, the productivity slowdown affected almost all the advanced economies. Research from the Conference Board (which builds on data from the OECD, Eurostat and other international organizations, including the Asian Development Bank (ADB)) shows the pattern of the productivity slowdown. They use a technique called a Hodrick-Prescott filter, which takes the annual productivity data and smooths the year-by-year growth numbers to pick out the longer run trends.

Chart 2 shows their results for Japan, the UK, the United States, and the Euro area. The figure finds that productivity growth in Japan, which was very rapid in 1970 (and before), has been slowing almost continuously since then. Productivity growth in the UK was stable for a period but has been slowing dramatically since the mid-1990s. Growth was slow in the United States in the 1970s and then had a period of faster growth before slowing again (consistent with the data shown in Chart 1). The euro area has also been slowing monotonically since the data for the combined area started. The line for the world economy is also shown and reveals that global productivity growth has been slowing since the mid-2000s.

The results shown in Chart 2 must be interpreted cautiously. For example, the line for the United States shows productivity growth starting to improve by the early 1990s, a finding not visible in the year-by-year data. It happens because the Hodrick-Prescott filter program creates a smooth line and does not allow abrupt changes.

Chart 3: Labour Productivity Levels in Selected Major Economies, 1970-2019 (USD)



Source: OECD Statistics

This approach is particularly unreliable at beginning and end points of the period considered.[8] Despite this reservation, the filtered data shown in Chart 2 provides a way of seeing patterns that would otherwise be obscured by numbers that change with each new observation. The pattern shown in Chart 2 illustrates an important point: The economies of Japan and Europe grew very rapidly in the postwar period, coming close up the productivity level of the U.S. economy. However, this growth has slowed very markedly, even falling below the slow U.S. pace.

To provide additional insight into productivity patterns across countries, Chart 3 shows the levels of GDP per hour worked in four large economies: the United States, Japan, Great Britain (the UK), and Germany.[9] The calculations of GDP per hour worked are made correcting for differences in price levels using economy-wide purchasing power parity (PPP) exchange rates. By the end of the 1980s, the level of productivity in Germany had converged to that in the United States, and similar productivity convergence was true for several other European economies.[10] The period of fast growth in these converging economies had allowed them to catch up to the U.S. productivity level. However, that is not the case for Japan and Britain, and the gap is quite large for Japan following a spectacular catch up during the first few decades after the Second World War. That points to a further question or puzzle. How are the levels of productivity among different countries related and why has convergence

8 The chart shows US labour productivity of about 1 per cent in the 1970s, which is a surprising. US productivity growth was strong until around 1973 and slowed thereafter before recovering in the 1990s.

9 The OECD has constructed figures for Germany with adjustments for the effect of the reunification with East Germany.

10 Economic convergence is explored in Baumol *et al.* (1989) and Baumol *et al.* (1994).

been incomplete in some countries?

The discussion so far has been based on aggregate measures of productivity and while the study of productivity at this level is valuable, we know that the economy is made up of thousands of companies that are grouped into many different industries. The speed of productivity growth and its determinants are very different in, say, the construction industry compared to the computer industry.

In the remainder of this article, the emphasis will be mostly on lessons learned about productivity based on different industries and, in a brief discussion, lessons learned from analysis using firm or establishment-level data. Even if the ultimate goal is to understand aggregate productivity, it is important to look at the contributions of different industries.

Industry Contributions to Overall Productivity Growth

One way to determine the growth contribution of the individual sectors of the economy to overall growth is to make use of a result derived by using Domar aggregation (Domar, 1961). Evsey Domar showed how to measure the contribution of TFP growth in each industry to the overall growth of the aggregate economy. For example, we can estimate the contribution of, say, manufacturing to TFP growth in the business segment of the economy, or the contribution of retail trade, and so on for each of the parts of business. The methodology is explained in the productivity handbook written by the OECD.[11]

The results of the decomposition of TFP growth by industry for the business sector of the U.S. economy are shown in Chart 4, in the 1987-2019 period.[12] The analysis starts in 1987 because prior to that year, U.S. industries were defined differently (computers and electronics was not a separate industry prior to 1987, for example). Results are available for 2020, but the COVID-19 pandemic has impacted these and made the findings difficult to interpret.

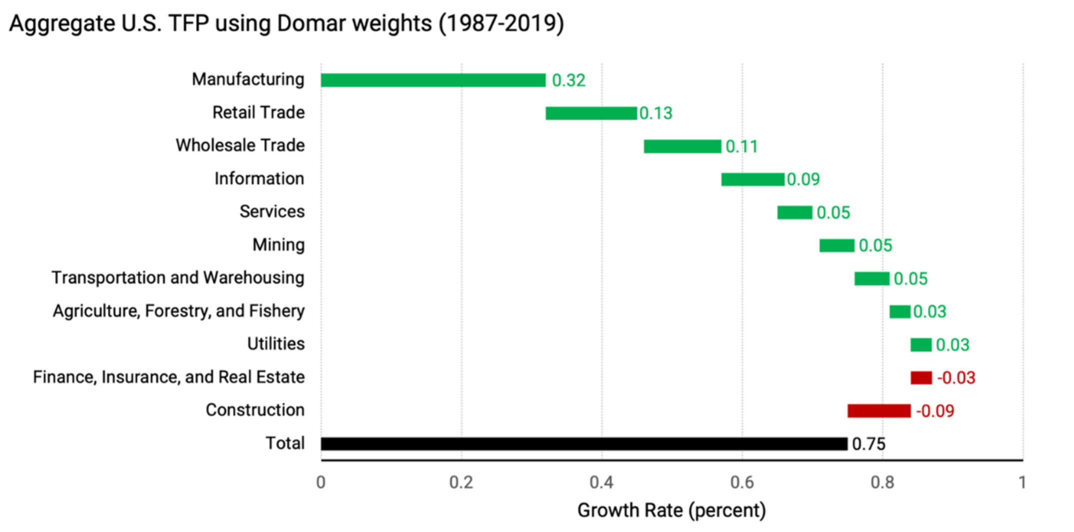
The immediate result revealed in Chart 4 is the enormous importance of a small number of industries to overall TFP growth in the United States.[13] Manufacturing, retail and wholesale trade and information account for TFP growth equal to 85 per cent of total TFP growth in the business economy. Services, mining, transportation, agriculture, and utilities all added positively to TFP growth while finance and construction both subtracted from growth, reductions in aggregate TFP growth. Perhaps the most striking result is the very large contribution from the manufacturing sector. It accounts for growth equal to 43 per cent of the total. That is not to minimize the importance of the other industries, but to note the surprising role of manufacturing given its modest size in the U.S.

11 This manual is updated regularly, see https://www.oecd.org/sdd/productivity-stats/2352458.pdf

12 This approach follows the approach pioneered by Harberger (1998).

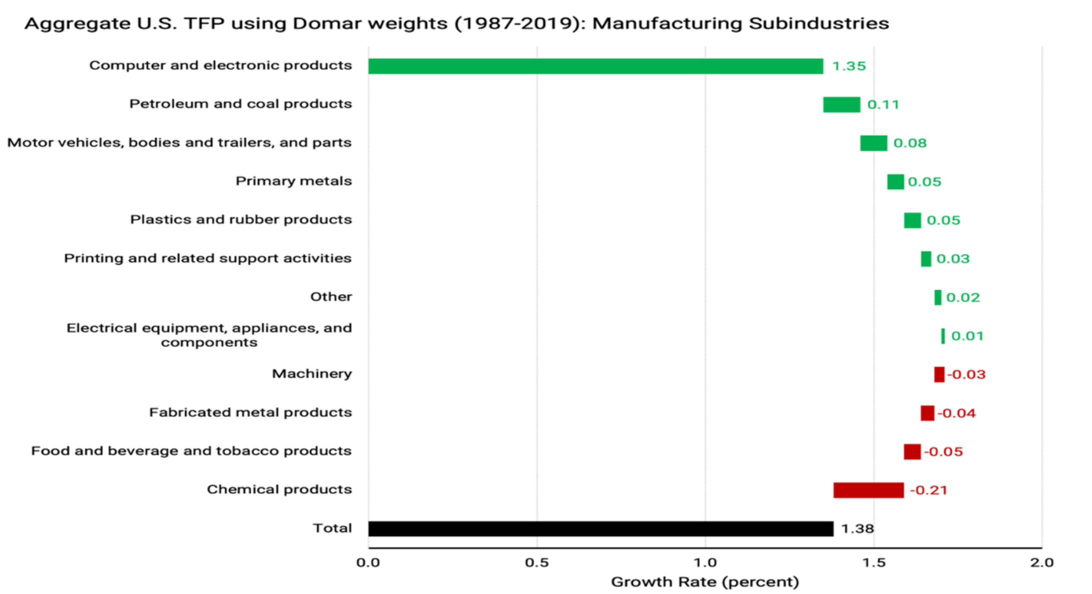
13 This statement applies to productivity calculations made using real output. Tang and Wang (2002) argue that the decline in relative prices of fast-growing industries reduces their contributions. For certain purposes, that is correct, but generally the use of real output to measure productivity contributions is preferred. See the discussion of the issue by Reinsdorf (2015).

Chart 4: Contributions by Industry to TFP Growth Using Domar Weighted in the U.S. Business Sector, (Percentage Points per Year), 1987-2019



Source: U.S. Bureau of Labor Statistics

Chart 5: Contributions by Subindustries to TFP Growth Using Domar Weighted in the U.S. Manufacturing Industries, (Percentage Points per Year),1987-2019



Source: U.S. Bureau of Labor Statistics

Table 1: Contributions to TFP Growth by Manufacturing Subindustry, Selected Periods, (Percentage Points per Year)

Subsector name	AVG 1987-2019	AVG 2014-2019
Computer and electronic products	1.352	-0.128
Petroleum and coal products	0.111	-0.021
Motor vehicles, bodies and trailers, and parts	0.079	0.005
Miscellaneous manufacturing	0.053	0.004
Primary metals	0.051	0.002
Plastics and rubber products	0.050	0.050
Printing and related support activities	0.033	-0.239
Textile mills and textile product mills	0.021	0.037
Nonmetallic mineral products	0.016	-0.016
Electrical equipment, appliances, and components	0.009	0.035
Paper products	0.004	0.036
Furniture and related products	-0.003	-0.028
Apparel and leather and allied products	-0.005	-0.094
Wood products	-0.016	0.272
Machinery	-0.031	0.038
Fabricated metal products	-0.039	-0.149
Food and beverage and tobacco products	-0.047	-0.08
Other transportation equipment	-0.050	0.024
Chemical products	-0.212	0.011
TOTAL (manufacturing):	1.377	-0.242

Source: Bureau of Labor Statistics, productivity database

economy. The contributions of retail and wholesale trade are also important.

The contribution of manufacturing is so striking that it is worth asking whereabouts in manufacturing this growth has originated. To answer this question, Domar disaggregation can also be made for the constituent parts of manufacturing. Chart 5 shows the results of doing this.

The remarkable finding from this analysis is that over the period 1987-2019 is that the TFP growth came from one industry, computer and electronic products.[14] As in Chart 4, there are positive contributions from other industries, but these are not very large and are offset by negative TFP changes elsewhere, particularly in chemical products. Chart 4 tells us that while the high-tech sector in the United States is not very large in terms of employment and share of GDP, it is very important to productivity growth.

Another important result obtained by looking at the manufacturing subindustries is to see which of them experienced slow growth in recent years. The findings are shown in Table 1 using percentage points. The most striking finding in the table is the fact that the computer and electronic products industry appears to have experienced negative TFP change over the period since 2014. Thus, by far the largest driver of manufacturing productivity over the full period and one of the largest drivers of productivity growth in the full business economy experienced a productivity setback in

14 Activities in the United States are assigned to industries on the basis of the most important activity in the establishment surveyed. Facebook, Netflix, and Google are all service industries, business or consumer services. Apple no longer manufactures in the United States. Amazon is primarily in the wholesale and retail industries.

the 5-year period prior to the start of the pandemic.

The fact that some industries and subindustries show periods of negative TFP growth is surprising. Indeed, over the short period 2014-19 the whole manufacturing sector had negative TFP growth. It is natural to think of TFP growth as representing technological progress or other business improvements. Why would companies or industries go backwards? There is no easy answer to this question, and it could reflect errors in the data. Perhaps capital or labour inputs have been miscalculated; our knowledge of productivity is imperfect, and we should not over-interpret any finding.

That said, the finding of negative TFP over a period of years may also reflect difficulties being faced by some or all the firms in an industry; perhaps their capital investment decisions were poorly made, and the capital is not being used in the way that was intended. Workers may produce output that is never sold. Keep in mind that TFP is calculated as residual, a measure of our ignorance, as Abramovitz described it.[15] Still, negative TFP is a warning of possible problems within an industry that can be investigated further.

Learning from Business Economics Research

In the early 1990s a nonprofit group, the McKinsey Global Institute was created to research important economic issues that could be informed by the knowledge provided by experienced business consultants working with leading economists.[16] It was decided that a central focus of the research would be to compare productivity across countries by industry and try to understand why differences occurred. This is a natural topic because of the knowledge consultants have of how firms and industries operate in many countries. Robert M. Solow was brought in to chair the academic advisory committees formed for each study and, for the first study, he asked Francis Bator and me to make up the other members of the committee.[17] Over time a range of different economists joined the projects with an emphasis on adding economists from the countries being studied. Leading economists such as Olivier Blanchard and Barry Bosworth contributed, as did Nobel Prize winners such as Robert Solow, Mike Spence, and Chris Pissarides. The results of the studies were always published in extended reports. Several of the studies were presented in articles in the *Brookings Papers*. William Lewis (2004), who led the

15 Abramovitz (1956). There are inevitable biases in the calculation of TFP. For example, Houseman *et al.* (2011) suggest an overestimate of productivity while Guyenen (2022) and Baily and Looney (2017) point to underestimation of productivity (an earlier version of the Guyenen article was released as a working paper in 2017).

16 The group, the McKinsey Global Institute, was and is funded by McKinsey Company, a profit-making institution, but as a research group whose results would be published and made available to everyone. The project reports are available on its website. The studies were also discussed in published articles, including Baily (1993), Baily and Gersbach (1995), Baily and Garber (1997), Baily and Zitzewitz (1998), Baily and Solow (2001), Baily *et al.* (2005), and Lewis (2004).

17 Francis Bator left the advisory group in the mid-1990s. He was the one who suggested the causal framework that was then used in all the productivity studies.

teams in the 1990s, wrote the book *The Power of Productivity* about this work, and Solow and I wrote an article in the *Journal of Economic Perspectives* (Baily and Solow, 2001).

This section will describe some of the findings from this work in some detail but first a summary paragraph highlighting the most important findings. First, the studies found that there were large differences in the levels of productivity across countries in the same industry. At the time of the research, there had not been a full productivity convergence among advanced economies at the industry level. Second, a high level of competitive intensity forces firms to achieve the level of productivity of the best performers in their industry, or close to it. And if companies compete against the most productive companies world-wide, they move closer to that best-practice productivity level. Third, certain types of regulation, as well as trade and investment restrictions, can prevent an industry in a country from achieving best-practice productivity. Fourth, operating at large scale often provided a productivity advantage. And fifth, promoting high productivity is not a simple thing. The drivers of productivity or the barriers to productivity varied by industry and country. There were occasional surprising exceptions to the general rules outlined above.

Most of the productivity studies I discuss here were carried out in the 1990s through the early 2000s, so the specific numbers used to draw the conclusions will not necessarily reflect the relative productivity status of the industries today. The competitive dynamics may have changed over time and regulation and trade rules may be different than those that applied when the studies were carried out. The lessons for productivity are not out of date, I believe, and will give insight into important determinants of productivity that still apply today.[18]

The Role of Capital

Capital goods are obviously essential to production in almost all economic activity. A modern factory is full of equipment. Offices are housed in expensive buildings, with furniture, fixtures, and office machinery, computers for all employees, mainframe computers for accounting, billing, and other tasks as well as copiers and telecommunications equipment. All high-income economies are built on a capitalist model, even those that have state ownership of some companies. It was natural for economic models of growth to single out capital as the key factor of production, and it was a shock when its importance to productivity growth turned out to be smaller than expected.

Given that history, it probably should not have come as a surprise when cross-country productivity comparisons did not find differences in capital intensity across the advanced economies to be a substantial cause of productivity differences. Cap-

18 The McKinsey Global Institute has additional work that can be found on their website https://www.mckinsey.com/mgi/overview. The article by Gouma and Inklaar (2023) in this issue of the *International Productivity Monitor* provides an excellent comparison of different data bases, including those of the Conference Board, the OECD, the KLEMS database and others.

ital might have been expected to show up as an important cause of productivity differences in manufacturing industries, but instead it was found that factories were equipped similarly across these economies. The companies that make capital goods sell them around the world, so factories in different locations generally have comparable equipment and look very much the same. There can be differences in the utilization of capital and smaller companies may not use the most up-to-date machinery, especially in developing economies.

As noted earlier, there is much complexity involved in productivity, and so there are qualifications to the above statement. Capital goods are expensive and last a long time, and they embody the technology available when they were constructed. The technology embodied in the capital can vary across economies. There were examples where a recently built factory is more productive than older factories. For example, Korea set up Pohang Steel Company that began operations in 1968 with a state-of-the-art factory supplied from Germany that was for some years one of the most productive integrated steel mills in the world (Baily and Zitzewitz, 1998). A more recent example of the value of advanced machinery, as described in press reports, is that Tesla uses very advanced capital goods to achieve high levels of productivity.[19]

The finding about the role of capital intensity has also been questioned in the UK where capital intensity is substantially lower than in Germany. On the face of it, UK companies should have good access to capital through the strong financial sector in the UK. But it is argued that UK companies demand very high rates of return on investment and seek those returns through foreign investment rather than improving productivity domestically (Bughin *et al.*, 2018).

Despite such qualifications, the productivity studies found in most cases that the way factories or offices or retail facilities were operated were much more important to productivity than differences in the capital stock. Organizational or managerial capital was very important. And there were even examples where high levels of investment had contributed almost nothing to productivity. The study of Korea, for example, found that government development policies had, in some industries, encouraged overinvestment where machinery was underutilized. Another example came from Germany where union restrictions on shiftwork meant that companies had to invest in extra capital to produce a given level of output and capital utilization was low compared to the United States.

The Role of Human Capital

The level of education of production and non-supervisory workers was not found to be an important determinant of productivity. A striking example came from a comparison of residential construction in Brazil and the United States. Productivity was very low in Brazil, only about one-fifth of the U.S. level. The conventional wisdom in

19 Rauweld (2021) describes the speech made by VW CEO Herbert Diess in which he warns VW employees they will have to improve their own productivity substantially to compete effectively against Tesla.

Brazil was that this low productivity was the result of the low educational level of the construction workers. Most had received only a few years of education, and many were unable to read and write. However, a comparison of residential construction sites in Brazil and in the United States found that most of the U.S. construction workers were immigrants (mostly from Mexico) who had also only completed a few years of education, and most were unable to read and write. Instead, the productivity difference arose from two main reasons. First, most U.S. residential construction is carried out in sites where a large area is cleared and then multiple copies of pretty much the same house is built. This allows economies of scale. Second, a U.S. construction site is carefully orchestrated by site managers. Special trade workers, such as plumbers, carpenters and electricians are brought to the site only when required. These workers move from site to site as needed. Utilization of labour is much better in residential construction in the United States.[20]

The retail industry provided another example where education was not seen as important for non-supervisory workers. Retail companies such as Wal-Mart do not require much education for their workforce. Worker productivity is achieved through training, the design of work procedures, and through performance incentives. Big-box retailers like Wal-Mart typically have very high levels of staff turnover and build productivity into the business system rather than relying on worker skill.[21]

There is a contrast with some German retailers in the 1990s that had apprenticeships where cashiers were required to memorize all the products the store so that they could cash out customers quickly without checking price labels. The arrival of universal product codes and scanners rendered that skill unnecessary. Indeed, scanners are much more productive since they can be used for inventory management.

As with the construction example, the managers and computer systems engineers at productive retailers are very skilled and designed systems to coordinate wholesale and retail functions and ensure deliveries were on time and sent to the right store.

A similar story applies to the fast-food industry, where the staff in the outlets often do not have much education. They receive basic training to perform the tasks they are assigned, and the layout of the premises and the design of the equipment allows high productivity. The cash registers make change and do not require a knowledge of English. The cooking is monitored by the fryers and ovens. This describes low-cost outlets like Mcdonald's, but even higher-priced restaurants use factory-prepared components that are cooked and assembled using carefully worked out procedures, rather than skilled chefs.

20 The MGI international comparison studies found the level of residential construction labour productivity to be relatively high. However, the growth rate of construction labour productivity in the United States has been very low or negative, see Goolsbee and Syverson (2023).

21 Some big box stores have skilled workers on the floor. Hardware store employees, for example, must provide advice and guidance if the store is to attract non-expert customers and the same is true for computer retailers and some parts of consumer electronics retailing.

The Importance of Human Capital: Can these Findings be Correct?

There is a huge economics literature that makes the case for the importance of education to wages and to the economy. Alan Krueger, for example, working with Joshua Angrist, found that the accident of birth date impacted how long some students stay in school and that even staying a few extra months in school added to lifetime earnings (Angrist and Krueger, 1991). Krueger and Orley Ashenfelter (1991) used identical twins to demonstrate the contribution of education to earnings. Claudia Goldin and Lawrence F. Katz in *The Race Between Education and Technology* in 2008 argued that the demand for and supply of human capital have shaped the distribution of earnings in the United States. Baily, Bosworth, and Kennedy (2021) argue that differences in human capital returns in Japan relative to Germany and the United States play a role in productivity differences.

It is hard fully to resolve the difference in conclusions between the productivity studies from the business consultants and the academic findings on the value of education, but the following ideas may help.

First, skilled managers, scientists, engineers, and professionals are important in creating productive companies and in developing new technologies. The strong universities in the United States have contributed to the supply of this segment of the workforce and encouraged creativity, innovation, and entrepreneurship. Nothing in the productivity studies contradicts this.

Second, there are different ways of running productive companies, described in the labour economics literature as the high road and the low road. With exceptions, U.S. companies take the low road, building productivity into their business systems, setting low wages for production and nonsupervisory workers, and accepting high rates of turnover. Again, with exceptions, German companies take the high road, relying on well-trained workforces and creating high-quality outputs—using a different business system model. German manufacturing is much bigger than the sector in the United States, adjusted for the relative sizes of the two labour forces. It pays good wages and runs a huge trade surplus supplying specialized and high-quality products around the world. The two countries end up with similar productivity levels.

Third, the economy is changing. In the past, a high school diploma or a degree from a community college was enough to allow Americans to obtain a good job and earn a living wage, often in a unionized company. Even if companies did not especially value the specific knowledge acquired in high school beyond basic skills, they did value the signal provided by a diploma which demonstrated the willingness to work hard and to accept training. The widespread dissatisfaction with the available pool of jobs, and the social antagonisms that have been the result, demonstrate that America's low-road approach is creating problems. The inability of many students to handle student loans suggests that spending extra time in school does not raise wages much for many students.

The Role of Technology and Innovation

There is a great emphasis on technology, and advanced technology particularly, as a source of productivity growth. This goes back to the original growth models where the TFP residual was seen as coming from technological change. In the MGI cross-country comparison studies, however, the importance of high-tech was questioned. The high-tech sector is small in all countries, even in the United States or Japan. Its share of employment and GDP are both small. Nevertheless, the products and services of this sector could be important in influencing productivity elsewhere in the economy. The comparative studies found, however, that proprietary technology was not a major source of productivity level differences across economies. The reason for this is that most technology products are available on global markets. Machinery and equipment, including computers, are sold around the world and so is software. We gave the example earlier of the Korean steel industry, where a huge integrated steel mill was built using the most advanced available German capital goods.[22]

Product and process designs and organizational technology (called intangible capital, or sometimes "soft" technology) can be hard to transfer internationally and can depend on a company's specific skills and culture. One of the best examples of this came from the automobile industry. The Japanese auto industry in the 1990s was substantially more productive than the industry in the United States or in Germany.[23] Toyota was acknowledged to be the global productivity leader, although other Japanese companies had adopted many of the practices used by Toyota. The Toyota production system had been developing gradually for many years and it involved three main elements. First, incremental improvements were constantly made on the production line to reduce wasted time and materials and to make sure parts were available at the right time and in the right location. This efficiency was achieved by checking and redesigning the process and by using suggestions made by workers on the line.

Second, the cars were designed to make them easy to assemble. Parts were simplified and designers looked for ways to reduce the number of parts needed. Parts could be fitted together easily and secured in place with a minimum of time. One consequence of these design improvements was that the cars became much more reliable. Japanese cars sold in the United States could be priced at a premium because of the reputation they developed for reliability.

The third important element of the Toyota production system was the way in which the company worked with their suppliers as part of a keiretsu. The suppliers formed a close relationship with Toyota, a pattern that was replicated with other Japanese original equipment manufacturers (OEMs). Engineers from the OEM would visit the supplier factories and make suggestions for ways to cut costs and improve designs or quality. The OEMs would maintain their relationships with

22 I will come back to the technology issue later in this article. Another issue raised about technology, particularly information and communications technology, is how much of the value from advances in this area accrue to the innovating country and how much is transferred globally through falling prices of hardware.

23 Based on a quality-adjusted number of vehicles per hour.

their suppliers over long periods, although it was made clear that suppliers were expected to make continuous improvements. The American companies, instead, developed arms-length relationships with suppliers, generally requiring that more than one company supply components. There would then be pressure placed on the suppliers to reduce component prices. This would squeeze profitability and make it difficult for the suppliers to invest in new equipment or do R&D to improve quality or to improve designs. Over time, many parts suppliers moved operations to Mexico or other low-cost supply locations.

It proved very difficult for American companies to adopt the Toyota production system. This is surprising because it did not involve proprietary technology; indeed, Toyota formed a joint venture with General Motors in the 1980s (NUMMI) in a factory in Fremont, California. GM executives visited this factory but did not try to transfer the technology to their U.S. operations for many years. The reason for the unwillingness to adopt the Toyota-led improvements in production methods was that GM had become the largest and most successful company in the world in the post-World War II period. Its managers were convinced, they had the best ways of doing things. Major changes only happened when competition, and ultimately bankruptcy, forced the changes. Ford learned about Japanese production technology through its partnership with Mazda and did transfer some aspects of the system, notably in the design and production of the successful Ford Taurus.

What Factors in the Economic Environment Determine Productivity Differences?

Several factors have been listed above as not being central to productivity differences and one factor was listed as significant and more important than is often realized—organizational or intangible technology. This subsection takes the story further by asking what factors in the economic environment contributed to companies and industries achieving global best practice productivity. The answers are: first, competitive intensity forces improvements; second regulation can impede productivity advance; and third, scale can allow higher productivity operations.

In the comparisons of manufacturing industries across advanced economies, the most productive industry across the different countries was identified as the global leader in productivity in that industry. For example, in automobiles the Japanese industry was the leader and the industries in other countries were considered follower industries. The leader industry was then assigned productivity of 100 and the relative labour productivity of follower industries was measured relative to the leader.

A second calculation was then made as to how much the industry a country was "exposed" to the productivity leader. This calculation was based on three elements. First, does the industry compete in its home market against companies originating in the country of the productivity leader? For example, when Japanese companies built factories in the United States, this forced the U.S. auto industry to compete directly against Toyota, Nissan, and other companies. Second, does a given industry compete against the leader through trade in third markets? For example, how much does, say, the German industry compete against the Japanese industry in its export sales? And third, does an industry sell into the market of the productivity leader? These three factors were then weighted into an index, the globalization index, measuring the exposure of each of the follower industries to the productivity leader.[24]

It was then found that exposure to direct competition with the global productivity leader forced an industry to improve its own productivity in response to the competitive pressure. In contrast, those industries that were protected against competition from the global productivity leader tended to have lower productivity. Baily and Gersbach (1995: Chart 7) show the positive correlation between an industry's productivity relative to the global leader and the index of its exposure to competition is shown. The resulting correlation is not perfect, but it is strong. It shows that when a manufacturing industry competes against the best global companies in their industry, this forces them to improve their own productivity to try and keep pace.

The correlation confirmed the view of the business industry experts, and applies also, they judged, to service industries. Industries that are protected from competing against the best global companies in their industry will often form comfortable oligopolies that do not strive to be more efficient but are content to make adequate profits and avoid risky changes or expensive investments in new methods or products.

The measured level of productivity in an industry depends on both the level of output and on the level of inputs. Improving productivity will often mean finding ways to produce the same output with fewer inputs. But raising output without a comparable increase in inputs will also increase productivity. For example, products that are well-designed and reliable can be sold at a higher price, boosting output and hence productivity.[25] Alternatively, a company that understands what consumers are looking for and can follow shifting tastes can avoid excess capacity and use its workers and equipment more effectively.

The effect of *regulation* was found to be strongly linked to the competitive intensity just described. The regulations that had a negative impact on productivity were those that limited competition. These limits could come from international trade restrictions (trade barriers of all kinds). Trade restrictions apply primarily to manufactured goods. Regulations can be used to restrict land use, making it impossible for a best-practice company to enter a market or compete. Restrictions on direct foreign investment make it hard or impossible for a leading global company to enter and op-

24 The details of the index are described in Gersbach (1999). Gersbach's index weighted each of the contributors to globalization equally.

25 Measuring this contribution can be tricky as it involves assessing quality differences. However, international comparisons try to make this comparison using products that are standard across markets. Then the price premium for higher quality products can be included in real output and hence in productivity. The OECD in its comparisons tries to use this approach and MGI made its own estimates. Statistical agencies have difficulty in making quality adjustments, which is why MGI often made its own attempts to make these adjustments.

erate in a given market. For example, Sweden had restrictions that prevented foreign banks from entering their market, with the result that Swedish banks had inefficiencies in their operations. With their entry into the EU, Sweden opened its market and allowed foreign banks to enter and force the domestic banks to become more efficient.

Sometimes there were regulations that were idiosyncratic, affecting one specific industry. For example, Germany is very proud of its beer and had complex regulations arounds its production. So-called purity laws restricted how production is carried out and in some cantons the beer sold in a canton had to be manufactured within the canton. German beer is of high quality, but the proliferation of small subscale breweries resulted in low productivity. It was judged that the beer made in Germany could be made with optimal-scale plants at higher productivity without sacrificing quality if regulations were eased.[26] The production of sake in Japan also faces similar restrictions.

Labour regulations can also impact productivity in two main ways. First, union rules may restrict the ways in which companies can improve their production processes. For example, it was noted earlier that General Motors was able to see how a Toyota plant operated through its joint venture in California, but they did not bring these ideas back to their own plants in Michigan, at least not for many years. One reason was a belief that they did not need to change, but another reason was that the union did not want to operate using the Toyota production process, believing that the Toyota approach would undermine the worker protections they had in place. In addition, union pressure can lead to trade restrictions or other regulations that protect jobs but hurt productivity.

In Europe, unions in many industries resisted change on the grounds that jobs would be lost. EU rules were intended to force member countries to open their markets, but not all countries followed these rules to the same degree. Countries such as Italy and Portugal had very entrenched companies and unions that resisted change. By contrast, Sweden was able to open its economy to competition; it had unions that were more focused on international competition, and it achieved very strong productivity growth in the 1990s.

I take seriously the concerns of labour unions to protect their workers. Automation and international trade have eliminated many well-paid jobs and caused social discontent. Ideally, countries should retrain workers that are made redundant and protect them from income losses, but not all countries do this well. Sweden is a

26 The conclusion in the MGI studies about the productivity in the German beer industry was controversial, especially in Germany. One can make the argument that German consumers were simply expressing a preference for locally made beers, which were higher quality in their view. Of course, one way to test this is to deregulate and see if consumers still choose the local beers. Since this study was carried out there has been a proliferation of small-scale breweries in the United States, competing against the giants such as Budweiser and Miller. This does not undermine the argument made for Germany. The key question is whether high-productivity large-scale breweries are permitted to compete in the market. If they can, but consumers choose to buy beer from small local breweries, then the local industry is productive and efficient. The higher price of the local breweries allows their quality-adjusted productivity to match the large-scale producers.

country that combines strong productivity with protection of workers. German manufacturing unions protect their workers but also recognize that companies must remain internationally competitive. German training programs allow workers to move to different jobs when necessary.

The example of the beer industry leads into a broader discussion of scale. There are scale economies in production in many industries, in fact pretty much all industries up to a certain production level.[27] Scale economies were not found to account for large productivity differences across advanced economies for the most part. The German beer example is an exception rather than the rule. Mostly companies operate plants at sufficient scale that allows them to be productive. Still, there are some advantages to scale and access to a large market. Large companies can spread fixed costs over high production levels, giving them a better chance to spend on R&D or on other forms of product or process development. Large companies can experiment and try new products or new process designs and cover the cost if these turn out to be failures. Of course, size is no guaranty of success. General Motors was the largest auto company in the world but ended up in bankruptcy. IBM dominated mainframe computing in the past but is a much smaller company today.

The one consistent effect of scale found was that richer countries produce and sell more goods and services that are higher value-added and have higher measured productivity. Luxury cars and luxury hotels can be sold with higher margins than budget cars and motels. The United States, which has both a large market and many rich consumers, achieves a modest productivity advantage from these characteristics. The EU, of course, has now created a market that matches the U.S. market in size and China's market has grown to match these in size, although China still has a lower GDP per capita than the advanced economies.

What Determines the Productivity Leader?

The simple answer to this question is that we do not know exactly why innovation occurs in one location rather than another. There is serendipity involved in innovation; chance plays an important role. That said, there are economic conditions that favor innovation, and there are policies that can make innovation more likely. Factors that support innovation are discussed below.

A high level of competitive intensity, as we have seen, encourages companies to adopt available best practices—to catch up to the productivity leaders—but it also encourages productivity leaders to innovate to maintain an advantage over their competitors. That advantage may be only temporary, but leading companies innovate continuously to stay ahead.

Innovation involves the development of

27 An inverse U-curve has been found between productivity and size, but the specifics considerably vary by firm and industry. There may be scale advantages with large plants (up to a point). There can also be advantages to firm size, allowing more scope for experimentation and research. But there can also be problems in managing very large firms.

new products and processes.[28] Although competition favors innovation, an industry that is fragmented, consisting of large numbers of small companies, may not be innovative, at least not without help. Agriculture provides an example. In the nineteenth and early twentieth centuries, this industry in America consisted of thousands of small farms. Some farmers were innovative and found new ways to increase their production, but for the most part farmers were too busy keeping their farms operating to spend time and resources on innovation. In response, government stepped in and created research departments in universities, research laboratories, and agricultural extension programs to create and disseminate innovation to this sector. Agriculture has achieved very strong productivity growth in the United States.

The previous example illustrates one way in which government can play a positive role in innovation, and there are other examples. Government can encourage and support research efforts whose results are then available to all companies. They can also foster diffusion-oriented research to see how to obtain and adapt existing products or processes for their own companies. The German government has provided consistent financial support for the auto industry in that country, with research facilities and training. Government can also give research grants to the private sector to encourage new industries. Such grants were important in the early days of Silicon Valley, where Stanford University formed a research park to take advantage of the emerging opportunities in semiconductors. Government support has also been vital in the emergence of other research hubs, such as Research Triangle in North Carolina and the companies around Cambridge University in the UK. The Defense Advanced Research Projects Agency in the United States has famously supported innovations. Another important way in which government has supported innovation historically is as a customer. In the early days of integrated circuits, the U.S. Defense Department was the largest customer.

Another historically important role for government is through the patent system. Innovating companies can patent their inventions and create a monopoly for 20 years from the date the patent is filed in the United States and Europe. Patents are a way of providing incentives for companies to spend on R&D and product or process development. Current thinking is that the patent system has both negative and positive impacts on innovation. The industry that has benefitted most from the patent system is the pharmaceutical industry, where new drugs are patented, and the developing company can earn huge returns for their successful products. The disadvantage is that patients or insurance companies then pay high prices for medications. European countries mostly limit the ability of drug companies to charge high prices. Patents can also discourage innovation. For example, an electronics company that holds a key patent can make it

28 The diffusion of innovation involves the spread of these new products and processes around an industry or globally. As we note in this article, for many companies and countries it is most important to learn about the innovations that have already been developed and learn to use them.

costly or impossible for other companies in the industry to innovate in the same technological area. In the early days of Silicon Valley there were cross-licensing agreements that allowed different companies to use each other's patents, but today there are lengthy, expensive court battles to enforce patents, with potentially negative effects on innovation. It is important that the patent and legal system in a country sets reasonable patent fees to encourage competition and innovation, not discourage it.

Creating an industry with productivity and innovation leadership depends on the availability of talented people with the right knowledge and skills. Generally, this is thought of in terms of people with scientific and technical knowledge, and indeed these skills are important, but innovative business ideas are just as important. Entrepreneurs who develop new business models are not necessarily technology experts, rather they are people with the vision to see opportunity and the willingness to take risk. An environment where failure is allowed and where venture funds are available is important.

Consistent with the findings of the MGI studies, there is now an extensive literature on how management competency impacts the performance of firms. See for example Bloom and van Reenen (2010), who worked with McKinsey in some of their work on this topic.

Lessons from Studies of Establishment Data

This section provides a short description of some of the findings that have been obtained using government data collected from individual establishments. The US Census Bureau collects survey data on individual establishments. These differ from data on individual firms because large firms typically operate many different establishments, often in different industries. The Census Bureau's data allows for the study of specific industries, consisting of all the establishments producing roughly the same type of product automobile assembly plants, for example, or auto parts producers. The best data is available for manufacturing establishments, but there is some research that has extended to service industries as well. In an anonymized form, the data is made available to researchers. John Haltiwanger of the University of Maryland has been the economist that has helped develop the database for others to use and has published much research of his own.[29] I participated in this research effort in the 1990s.

Although this section will not do justice to the extensive literature that has emerged using the establishment data, which now extends to work in other countries, (in fact, Canada pioneered the development of such databases) here are a few important findings.

- Productivity growth in an industry comes from improvements *within* existing establishments, but also comes

29 See: https://econ.umd.edu/sites/www.econ.umd.edu/files/cv/Haltiwanger_cv_May_2023.pdf which contains extensive references to authors from around the world who have looked at micro productivity data.

from the relative expansion of the more productive plants and the relative contraction of the less productive plants.

- Plants that close (exit the industry) have lower productivity than the industry average. New entrants to the industry also tend to be lower productivity than the average, but those that remain in operation increase their productivity more than the average and move up in relative productivity.
- The distribution of productivity levels within industries has become wider. That is to say, the gap between the low-productivity establishments and the high-productivity establishments has increased.

The first two points illustrate the importance of the dynamics among plants to overall productivity growth. These findings are consistent with the results from the business studies. A competitive industry will have establishments that are more successful and some that are less successful, and if the more productive ones expand their share of the market, that is a boost to overall productivity. The establishments that are failing will eventually go out of business. Similarly, a dynamic industry will see new establishments entering the industry, starting with low productivity, but then either growing and moving up the distribution, or else dropping out.

These first two results come mostly from studies in the 1990s or early 2000s. The studies showing the increasing gap between low- and high-productivity plants come from more recent research. This is a sign that the dynamic movement of establishments within an industry that contributed to productivity in the past has slowed down. Low-productivity plants are remaining in operation even though they are not catching up to the best plants in their industry. That result is consistent with fact that productivity growth has been slower since 2004. Based on this finding, Decker, Haltiwanger, Jarmin and Miranda (Decker *et al.* 2016, 2020) find that the dynamism in the U.S. economy has declined. The gap between low- and high-productivity establishments has increased, consistent with the slowing of overall productivity growth.

The increase in the gap between the high and low-productivity plants has also been found for other countries. A study from the OECD using an international database, led by Dan Andrews, found that the most productive companies were pulling away from the rest of their industry (Andrews, Criscuolo, and Gal, 2016). The best companies had continued to see labour productivity growth even when their industry on average had shown slow or no growth. This study suggested that the declining dynamism and slowing of competitive dynamics seen in U.S. data may also be true in Europe and elsewhere (except for the firms at the very top of the productivity distribution).[30]

Have the Key Questions Been Answered?

The first four questions posed at the beginning of this article are all related. Re-

30 Gutierrez and Philipon (2017) argue that the US economy has become less competitive.

search has found that overall productivity growth is tied to TFP and has been associated with technological progress. The answers to all four of these questions are tied to an understanding of TFP—where did it come from during the period of fast growth, why did it slow down (and then speed up and slow down again), and why does its level differ across countries? While not all the puzzles have been answered, there are lessons that have contributed to an understanding of them.

- Innovation, broadly defined, must be the source of productivity growth for firms at the productivity frontier. Technological developments coming from science and engineering are one important source of innovation, but soft innovations are important also, often more important. These take the form of new business models, new products and redesign of old products, and improvements in existing processes. These innovations have contributed strongly to TFP growth over time. And differences in the application of this type of innovations help explain productivity differences across countries.
- The path to a higher level of productivity for most industries in most countries is to learn about the best-practice innovations made around the world and take advantage of them. In some cases, access to best-practice productivity can be limited by trade secrets, patents, or by the complexity of operating at the productivity frontier, but in most cases the necessary technology is available in the global market through capital goods suppliers, software suppliers, and business consultants. If it is too difficult for domestic companies to reach the productivity frontier, a country can encourage direct foreign investment to bring best-practices into their economy. At the beginning of 2022 the United States hosted over $14 trillion of foreign direct investment mostly from leading global companies.[31]
- Important reasons identified for the productivity gaps across countries are restrictions and regulations that protect companies with weak productivity, including restrictions on trade and investment. The nature of the restrictions that limit competition can vary across industry.
- The business studies suggested the educational level of production workers may not be very important to achieving best-practice productivity. However, Germany has shown that high productivity can be combined with a well-trained workforce and this path provides greater equality for the workforce and greater opportunities for those people who do not obtain a college degree. In addition, Baily, Bosworth, and Kennedy (2021) argue that advanced education is important for managerial skills, R&D, and innovation.

31 Data from the U.S. Bureau of Economic Analysis, https://www.bea.gov/sites/default/files/2022-06/intinv122.pdf

- Although this study has not emphasized the issue, there is a consensus among economists that the period of rapid TFP growth in the United States that started in the mid-1990s and lasted until around 2004 was linked to information and communications technologies. In particular, the semiconductor industry was able to cram more circuits onto a single chip and increase the power of computers. Increased competition in this industry encouraged more rapid innovation. Improved computers and communications technologies also helped other industries to advance. Another large productivity contribution came from wholesale and retail trade, where big-box retailers expanded nationwide, coordinated their wholesale and retail functions, and pushed other companies to improve their own operations. By the early 2000s these sources of growth had faded, and growth slowed again. The drop in TFP growth in the computer and electronics industries since 2014, shown earlier, is one important sign of the ending of the technology-driven productivity surge.[32]
- The biggest mystery that remains in productivity research is to explain why productivity growth has been so slow in recent years across so many economies. The default explanation for this is that the pace of productivity enhancing innovation has slowed as the best sources of innovation have dried up.[33] As we saw in Chart 2, the pattern of slow growth is widespread and long lasting. What remains puzzling is that it appears to many that the pace of innovation has not slowed at all but instead is extremely rapid, with advances such as artificial intelligence, machine learning, robots, 3-D printing, and so on, and new companies, like Amazon and Uber, that are shaking up traditional industries. Presumably, all the technological change taking place today is not the kind that generates strong positive productivity effects, at least not yet (Brynjolfsson *et al.* 2021, and Bart van Ark, 2016).
- One important result is the very large contribution of the manufacturing sector to overall productivity growth and the very large contribution of the high-tech sector to manufacturing productivity growth. This result did not emerge from the 1990s cross-country studies, which focused on productivity levels (although subsequent research from the consulting company has emphasized the value of high-tech). This result also gave some insight into the slowdown in growth, a large portion of which comes from the slowdown in the high-tech manufacturing sector, as well as the reduction in the size of this sector as a result

32 An alternative view of the speed-up in technology is described in Lewis *et al.* (2001). This study stresses the importance of increased competition and the pressure on retail productivity from the expansion of Wal-Mart.

33 See Gordon (2016). Further analyses of the slowdown are in Byrne *et al.* (2016) and Baily and Montalbano (2016).

of outsourcing.[34] This finding also suggests a reason why the productivity growth that has been achieved has not done very much for average wages. The high-tech sector, in both manufacturing and services, has generated huge wealth for some, but it has also increased inequality and has not created many good jobs for those without advanced education.

Will there be a Surge of Productivity from Generative AI? [35]

The speed of technological change and the role of technology in productivity growth are hard to assess. Robert Gordon (2016) has argued that technological change has slowed. He finds recent innovations in information and communications technology to be underwhelming. Similarly, Paul Krugman (2023) suggested the internet has not produced much in the way of productivity improvement and he doubts that the latest breakthroughs will do much for future productivity. Recent history on the role of high-tech in generating stronger labour productivity has been mixed. In the 1980s there were substantial breakthroughs in computer technology and the introduction of the PC, but productivity growth remained stubbornly slow. However, starting in the mid-1990s, as discussed earlier, there was a wave of faster productivity growth linked to the rapid increase in the speed of computers, which became both much cheaper and easier to use. There were also big advances in communications technology.

The United States and the rest of the world may now be poised for another substantial step forward in digital technologies through the development of generative AI, that can use common language to solve problems and do a variety of tasks that were previously out of reach of computers. Given the recent past, it is important to recognize the uncertainty about the future productivity impact of this rapidly developing technology, but there are reasons to be hopeful that there can be another period of stronger labour productivity growth ahead.

One reason to be optimistic comes from the extremely rapid uptake of ChatGPT, a large language model (LLM) which is reported to have reached 100 million users only two months after its launch to the public.[36] This rapid uptake is like the wave of computer investment that took place in the 1990s. The new software is relatively cheap to buy, easy to use and can be very helpful to a great many people. ChatGPT, from the company OpenAI, can generate coherent and contextually appropriate text. Microsoft has invested in this program and made it available through its search engine Bing. And there is strong competition from other providers, such as

34 Dale Jorgenson highlighted the importance of high-tech manufacturing to growth and suggested that as Moore's law is exhausted, that will lead to slower overall growth. I learned this from a presentation of his that I attended a few years ago, but I have not been able to locate a specific reference where he stated this. There is an analysis of the sources of growth in Japan in Jorgenson *et al.* (2018).

35 This section draws on Baily, Brynjolfsson and Korinek (2023).

36 This was reported by Reuters February 2, 2023 https://www.reuters.com/technology/chatgpt-sets-record-fastest-growing-user-base-analyst-note-2023-02-01/

Bard from Google and Claude from Anthropic. These companies are investing heavily to improve their programs, which rely on huge server farms to support them. There are also other generative AI programs that can combine text, images, video and audio and even robotic functions.[37] One sign of the huge investment that is being made in generative AI is the amount of computing power being used to train the models has been doubling every six months over the past decade (Sevilla *et al.* 2022).

There are indicators that the impact of the new technology could be very large. Eloundrou *et al.* (2023) estimate that LLMs could affect 80 per cent of the workforce, to a greater or lesser extent (three of authors of this piece are from OpenAI while the fourth is from the University of Pennsylvania). And there are several case studies of specific jobs being made more productive described and cited in Baily *et al.* (2023). For example, software engineers were able to be twice as productive using a tool called Codex; it has been found that certain writing tasks can be completed twice as fast; and call center operators became 14 per cent more productive. Baily *et al.* (2023) also point out that the new technology has a potential to increase the returns from research and could, therefore, increase the rate of productivity growth, not just generate one-off improvements in specific tasks.

There are reservations about the impact of the new technologies. I mentioned already the skepticism about whether digital technologies can achieve much, but there are also concerns that it will have large but negative impacts. In the past 50 years technology has altered the demand for labour such that highly skilled/educated workers are in high demand while lower-skilled workers have seen weakness in their labour demand (skill-biased technical change). This is seen in the US labour market, but a similar trend has impacted other economies also. There is, therefore, a fear that there will end up being greater dispersion in wages and more dissatisfaction with the economy. This outcome is possible, particularly if firms fail to train their workers to take advantage of the new technology and if policymakers do nothing to help. However, a different outcome is possible. Many people find it hard to write coherent emails or to do mathematics. As a result, they are forced to take manual jobs with low wages. The new technologies can potentially help them to be more productive. There are signs from some of the case study evidence cited above that generative AI can help those with weaker skills become substantially more productive.

Rather than focus on the dangers of new technologies it would be better to figure out how to take advantage of them, mitigate the adverse impacts and use these breakthroughs to improve the economic future broadly.

Conclusions

While there remain unknowns, research into productivity has reached important

37 The program PaLM-SayCan combines the understanding of language models with the capabilities of a helper robot. https://sites.research.google/palm-saycan

conclusions that can provide a better understanding of the sources of growth and how business and labour leaders as well as government can contribute to faster growth. Even modest improvement in the rate of productivity growth can accumulate over time to generate substantial improvements in living standards. The world could use a boost to growth and, while much uncertainty remains, there are now new technologies that have the potential to achieve this.

References

Abramovitz, M. (1956) "Resource and Output Trends in the United States Since 1870," *American Economic Review,* Vol. 46, No. 2, pp 5-23. May.

Andrews, D., C. Criscuolo and P. Gal (2016) "The Best versus the Rest: The Global Productivity Slowdown, Divergence Across Firms and the Role of Public Policy," OECD Productivity Working Papers, No. 5 (Paris: OECD). https://doi.org/10.1787/63629cc9-en.

Angrist, J. D. and A. B. Keueger (1991) "Does Compulsory School Attendance Affect Schooling and Earnings?" *Quarterly Journal of Economics,* Vol. 106, No. 4, pp. 979-1014.

Ashenfelter, O. and A. Keueger (1994) "Estimates of the Economic Return to Schooling from a New Sample of Twins," *American Economic Review,* Vol. 84, No. 5, pp. 1157-1173.

Bahar, D. and S. Özdoğan (2021) "Innovation Quality and Global Collaborations: Insights from Japan," Global Working Paper No. 151, The Brookings Institution, January. https://www.brookings.edu/research/innovation-quality-and-global-collaborations-insights-from-japan/.

Baily, M. N. (1993) "Competition, Regulation and Efficiency in Service Industries," *Brookings Papers on Economic Activity: Microeconomics,* pp. 71-159. https://www.brookings.edu/bpea-articles/competition-regulation-and-efficiency-in-service-industries/.

Baily, M. N., B. Bosworth and K. Kennedy (2021) "The Contribution of Human Capital to Economic Growth: A Cross-Country Comparison of Germany, Japan and the United States," The Brookings Institution. https://www.brookings.edu/research/the-contribution-of-human-capital-to-economic-growth/.

Baily, M. N., E. Brynjolfsson and A. Korinek (2023) "Machines of Mind: The Case for an AI-powered Productivity Boom," The Brookings Institution. https://www.brookings.edu/research/machines-of-mind-the-case-for-an-ai-powered-productivity-boom/.

Baily, M. N. and A. Garber (1997) "Health Care Productivity," *Brookings Papers on Economic Activity: Microeconomics,* pp. 143-215. https://www.brookings.edu/bpeaarticles/health-care-productivity/.

Baily, M. N. and H. Gersbach (1995) "Efficiency in Manufacturing and the Need for Competition," *Brookings Papers on Economic Activity: Microeconomics,* pp. 307-358. https://www.brookings.edu/bpeaarticles/efficiency-in-manufacturing-and-the-need-for-global-competition/.

Baily, M. N., D. Farrell, E. Greenberg, J. D. Henrich, N. Jinjo, M. Jolles and J. Remes (2005) "Increasing Global Competition and Labor Productivity: Lessons from the US Automotive Industry," McKinsey Global Institute.

Baily, M. N. and A. Looney (2017) "The True Trade Deficit," *Wall Street Journal.* https://www.wsj.com/articles/the-true-trade-deficit-1495148868.

Baily, M. N. and N. Montalbano (2016) "Why is U.S. Productivity Growth so Slow? Possible Explanations and Policy Responses," The Brookings Institution. https://www.brookings.edu/research/whyis-us-productivity-growth-so-slow-possibleexplanations-and-policy-responses/.

Baily, M. N. and R. M. Solow (2001) "International Productivity Comparisons Built from the Firm Level," *Journal of Economic Perspectives,* Vol. 15, No. 3, pp. 151–172. https://www.jstor.org/stable/2696561.

Baily, M. N. and E. Zitzewitz (1998) "Extending the East Asian Miracle: Evidence from Korea," *Brookings Papers on Economic Activity: Microeconomics,* pp. 249-321. https://www.brookings.edu/bpeaarticles/extending-the-east-asian-miracle-microeconomic-evidence-from-korea/.

Baumol, W. J., S. A. B. Blackman and E. N. Wolff (1989) *Productivity and American Leadership: The Long View* (Cambridge: MIT Press).

Baumol, W. J., R.R. Nelson and E.N. Wolf (1994) *Convergence of Productivity: Cross-National Studies and Historical Evidence,* (Oxford: Oxford University Press).

Bloom, N. and J. V. Reenen (2010) "Why Do Management Practices Differ Across Firms and Countries?" *Journal of Economic Perspectives,* Vol. 24, No. 1, pp. 203-224.

Brynjolfsson, E., D. Rock and C. Syverson (2021) "The Productivity J-Curve: How Intangibles Complement General Purpose Technologies," *American Economic Journal: Macroeconomics,* Vol. 13, No. 1, pp. 333-372.

Bughin, J., J. Dimson, D. V. Hunt, T. Allas, M. Krishnan and J. Mischke (2018) "Solving the United Kingdom's Productivity Puzzle in a Digital Age," McKinsey & Company. https://www.mckinsey.com/featured-insights/regions-in-focus/solving-the-united-kingdoms-productivity-puzzle-in-a-digital-age.

Byrne, D. M., J. G. Fernald and M. B. Reinsdorf (2016) "Does the United States Have a Productivity Slowdown or a Measurement Problem?" *Brookings Papers on Economic Activity,* Vol. 47, No. 1, Spring, pp. 109-182.

Decker, R. A., J. Haltiwanger, R. S. Jarmin and J. Miranda (2016) "Declining Business Dynamism: What We Know and the Way Forward," *American Economic Review,* Vol. 106, No. 5, pp. 203-207.

Decker, R. A., J. C. Haltiwanger, R. S. Jarmin and J. Miranda (2020) "Changing Business Dynamism and Productivity: Shocks versus Responsiveness," *American Economic Review,* Vol. 110, No. 12, pp. 3952-3990.

Domar, E. D. (1961) "On the Measurement of Technological Change," *Economic Journal* Vol. 71, No. 284, pp. 709-729. https://doi.org/10.2307/2228246.

Eloundrou, T., S. Manning, P. Mishkin and D. Rock (2023) "GPTs are GPTs: An Early Look at the Labor Market Impact Potential of Large Language Models." https://ar5iv.labs.arxiv.org/html/2303.10130.

Gersbach, H. (1999) "Does and How Does Globalization Matter?" https://dx.doi.org/10.2139/ssrn.156768.

Goldin, C. and L. F. Katz (2008) *The Race Between Education and Technology* (Cambridge: Harvard University Press).

Goolsbee, A. and C. Syverson (2022) "The Strange and Awful Path of Productivity in the U.S. Construction Sector," NBER Working Paper No. 30845, National Bureau of Economic Research.

Gordon, R. J. (2016) *The Rise and Fall of American Growth: The U.S. Standard of Living Since the Civil War* (Princeton: Princeton University Press).

Gouma, R. and R. Inklaar (2023) "Comparing Productivity Growth Databases," *International Productivity Monitor*, No. 44. http://csls.ca/ipm/44/IPM_44_GoumaInklaar.pdf.

Gutiérrez, G. and T. Philipon (2017) "Declining Competition and Investment in the U.S." NBER Working Paper No. 23583, National Bureau of Economic Research.

Guvenen, F., R. J. Mataloni Jr., D. G. Rassier and K. J. Ruhl (2022) "Offshore Profit Shifting and Aggregate Measurement: Balance of Payments, Foreign Investment, Productivity, and the Labor Share," *American Economic Review*, Vol. 112, No. 6, pp. 1848-1884. https://doi.org/10.1257/aer.20190285.

Harberger, A. C. (1998) "A Vision of the Growth Process," *American Economic Review,* Vol. 88, No. 1, pp. 1-32.

Houseman, S. N., C. Kurz, P. Lengermann and B. Mandel (2011) "Offshoring Bias in U.S. Manufacturing," *Journal of Economic Perspectives,* Vol. 25, No. 2.

Jorgenson, D. W., K. Nomura and J. D. Samuels (2018) "Progress on Measuring the Industry Origins of the Japan-U.S. Productivity Gap," Working Paper, Harvard University. https://scholar.harvard.edu/files/jorgenson/files/pl01b_jorgenson_nomura_samuels_2018.pdf?m=1527941772.

Jorgenson, D. W. (2022) "Research," Harvard University website, https://scholar.harvard.edu/jorgenson/content/research-2.

Kendrick, J.W. (1993) "In Memoriam: Edward F. Denison, 1915–1992," *Review of Income and Wealth,* Vol. 39, No. 1, pp.117–119. https://doi.org/10.1111/j.1475-4991.1993.tb00442.x.

Krugman, P. (2023) "The Internet was an Economic Disappointment," *New York Times.* https://www.nytimes.com/2023/04/04/opinion/internet-economy.html.

Lewis, B., A. Augereau, M. Cho, B. Johnson, B. Neiman, G. Olazabal, M. Sandler, S. Schrauf, K. Stange, A. Tilton, E. Xin, B. Regout, A. Webb, M. Nevens, L. Mendonca, V. Palmade, G. Hughes and J. Manyika (2001) "U.S. Productivity Growth, 1995-2000," McKinsey Global Institute. https://www.mckinsey.com/featured-insights/americas/us-productivity-growth-1995-2000.

Lewis, W. W. (2004) *The Power of Productivity: Wealth, Poverty, and the Threat to Global Stability* (Chicago: The University of Chicago Press).

Rauweld, C. (2021) "VW CEO Tells German Workers Tesla Factory will Threaten Jobs," *Bloomberg.* https://www.bloomberg.com/news/articles/2021-11-04/vw-ceo-tells-german-workers-tesla-factory-will-threaten-jobs.

Reinsdorf, M. (2015) "Measuring Industry Contributions to Labour Productivity Change: A New Formula in a Chained Fisher Index Framework," *International Productivity Monitor,* No. 28. http://www.csls.ca/ipm/28/reinsdorf.pdf.

Romer, P. M. (1986) "Increasing Returns and Long-Run Growth," *Journal of Political Economy,* Vol. 94, No. 5, pp. 1002–1037. https://doi.org/10.1086/261420.

Sevilla, J., L. Hefm, A. Ho, T. Beslroglu, M. Hobbhahn and P. Villalobos (2022) "Compute Trends Across Three Eras of Machine Learning." https://arxiv.org/pdf/2202.05924.pdf.

Sharpe, A. and B. van Ark (2021) (eds.) "Symposium on the Decoupling of Productivity and Pay in the United States, the United Kingdom and Canada," *International Productivity Monitor,* No. 41, Fall. http://www.csls.ca/ipm/ipm41.asp.

Solow, R. M. (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, Vol. 70, No. 1, pp. 65-94. https://doi.org/10.2307/1884513.

Solow, R. M. (1957) "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics* Vol. 39, No. 3 pp. 312–320. https://doi.org/10.2307/1926047.

Swan, T. W. (1956) "Economic Growth and Capital Accumulation," *Economic Record*, Vol. 32, No. 2, pp. 334–361. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x.

Tang, J. and W. Wang (2004) "Sources of Aggregate Productivity Growth in Canada and the United States," *Canadian Journal of Economics,* Vol. 37, No. 2, pp. 421-444.

Tinbergen, J. (1942) "On the Theory of Trend Movements," *Weltwirtschaftliches Archiv*, Vol. 1, pp. 511-549.

van Ark, B. (2016) "The Productivity Paradox of the New Digital Economy," *International Productivity Monitor,* No. 31. http://www.csls.ca/ipm/31/vanark.pdf.