The Productivity Paradox of the New Digital Economy

van Ark, Bart

Published in:
International Productivity Monitor

The Productivity Paradox of the New Digital Economy

Bart van Ark
The Conference Board and the University of Groningen[1]

ABSTRACT
Despite a rapid increase in business spending on capital and services in Information and Communication Technology (ICT), the New Digital Economy (mobile technology, the internet, and cloud) has not yet generated any visible improvement in productivity growth. This article reviews the latest evidence for the United States, the United Kingdom and Germany. We find rapidly declining ICT prices, a shift from ICT investment to ICT services, and a continued increase in knowledge based-assets supporting ICT. However, the New Digital Economy is still in its "installation phase" and productivity effects may occur only once the technology enters the "deployment phase".

The rise of the New Digital Economy, defined as the combination of mobile technology, ubiquitous access to the internet, and the shift toward storage, analysis, and development of new applications in the cloud, is unquestionably altering the dynamics of economic growth. For example, over the past 15 years, business spending on digital services including cloud computing, data analysis, and other information services in major advanced economies (such as the United States, the United Kingdom, and Germany) rapidly increased. On the other hand, investment in digital assets (or ICT (Information and Communication Technology) capital), especially computers and peripherals, and communications equipment, has slowed significantly. Relative to average prices, prices of digital assets including computers and peripherals, communications equipment, and software have continued to decline rapidly, giving businesses large opportunities to operate at lower cost and higher efficiency and bring products and services to market at competitive prices.

Yet the New Digital Economy creates an important conundrum: as the economy is digitizing at such a rapid pace, why are we not seeing much faster productivity growth? Global productivity growth has been remarkably slow for almost a decade now, and there is little indication that the New Digital Economy has boosted productivity growth. Clearly there are multiple reasons for the slowdown in productivity since the mid-2000s, as discussed in the first section of this article.

In the second section, we argue however that the New Digital Economy is showing its effects under the radar screen of aggregate productivity growth. So far, the effects of the New Digital Economy are showing up most clearly in rapidly falling prices of ICT assets, increased spending

1 Bart van Ark is Executive Vice President, Chief Economist, and Chief Strategy Officer at The Conference Board in New York and Professor at the University of Groningen in the Netherlands. He thanks Carol Corrado and Abdul Erumban for comments and support. This article is based on a recent report by The Conference Board entitled *Navigating the Digital Economy: Driving Digital Growth and Productivity from Installation to Deployment* (Van Ark *et al.*, 2016). Email: Bart.VanArk@conference-board.org.

on ICT services rather than investment in ICT assets, and a critical shift towards the greater use of intangible assets, in particular ICT design and services, workforce training and organizational innovations. Despite the rapid diffusion of products and services based on the New Digital Economy among consumers, the business sector is finding it very hard to harvest the potential productivity gains as yet. The current evidence shows that only a limited number of firms have made a full transition to the New Digital Economy. Even fewer have already seen large benefits in terms of higher revenue, productivity, or profitability. As a result relatively few sectors and industries have seen visible productivity gains so far.

In the third section we make the case that the resolution of the rapid technological change-slow economic growth conundrum can be found in the fact that we are still in the "installation phase" of the New Digital Economy. This represents a period during which new technologies emerge and advance, driven by the creation of new infrastructure and new and superior ways of doing things, disrupting established practices and organizations. However, the productivity gains may not become visible until the "deployment phase" when the new technological paradigm will have been widely diffused and will have become common practice across organizations, enabling its full potential in terms of economic and business growth, productivity, and profitability. It is too early to say how large the productivity effects of the New Digital Economy will be during the deployment phase. But there is also no reason to be more pessimistic about future productivity effects compared to previous technology regimes.[2]

The Productivity Slowdown in the New Digital Economy

Since the mid-2000s, productivity growth has been showing a declining trend. This decline has been substantial, long-lasting, and across the board, and includes mature economies such as the United States, the Euro Area, and Japan as well as emerging markets such as China, India, Brazil, and Mexico. Globally, labour productivity growth (measured as output per worker) has only moderately slowed from 2.6 per cent per year, on average, in the 1996-2006 period to 2.4 per cent in the 2007-2014 period. The slowdown in global total factor productivity growth has been much more dramatic, downshifting from 1.3 per cent from 1999 to 2006 to only 0.3 per cent from 2007 to 2014.[3]

In earlier work at The Conference Board, we identified several reasons for the productivity slowdown, including the possible impact of the recent recessions (including the Great Recession in 2008-2009 and the Eurocrisis in 2011-2012) from which, in particular, the mature economies are still struggling to recover; the exhaustion of the potential for productivity growth in emerging markets; the intensification of regulatory and other policy measures that inhibit productivity growth; and the weaker translation of technology and innovation into productivity since the mid-2000s (van Ark *et al.*, 2015).

The slowdown in productivity growth in the past decade, especially in mature economies, is often attributed to the 2008-2009 recession and therefore considered temporary. However, in most countries, productivity growth already began to slow down before the recession and, except for a brief rebound, has not recovered to

2 See also the exchange between Sichel (2016) and Gordon (2016b) on Gordon (2016a) in this issue of the *International Productivity Monitor*.

3 See The Conference Board Total Economy Database (https://www.conference-board.org/data/economy-database/), November 2016. The periodization of the average growth rates refers to growth relative to the previous year, i.e. 1999-2006 refers to 1998 as the base year.

the growth rates of the 1990s and early 2000s. For example, between 2007 and 2014, growth in output per hour in the United States slowed to only 1.0 per cent per year on average, down from 2.4 per cent between 1999 and 2006 (Chart 1). In Germany, annual labour productivity growth slowed from 1.6 per cent per year to 0.8 per cent, and in the United Kingdom it weakened most dramatically from 1.9 per cent to 0.1 per cent. Even with an adjustment for faster declines in ICT prices (as described in the next section), and taking into account the shift toward purchased ICT services, these productivity declines remain.

Some economists are calling the current phase of economic growth one of long-term (or secular) stagnation, even though they may differ on the causes: either demand constraints due to disincentives to spend and invest, or supply constraints - such as slower labour force growth and weak productivity growth - that are restraining growth (Summers, 2016; Teulings and Baldwin, 2014; Gordon, 2016). Others are downplaying concerns of slow growth. They argue that while the effects of digitization and related technologies, such as nano- and bio-technologies and cognitive sciences, are becoming increasingly visible in the world around us, their impact on growth is not being well captured by current measurement techniques (Brynjolfsson and McAfee, 2011; Ford, 2015). While we are of the opinion that all of those factors are playing some role, it is also clear that without significant improvement in productivity growth, it is unlikely that stagnant growth in the coming decade can be avoided (van Ark, 2016). The need to prioritize productivity is underlined by the slowdown in growth of labour supply in the medium term, which could be up to one percentage point globally. To achieve similar GDP growth rates as during those times, labour productivity growth rates would therefore have to be higher by the same amount as the slowdown in labour supply in the next decade (van Ark *et al.*, 2015).

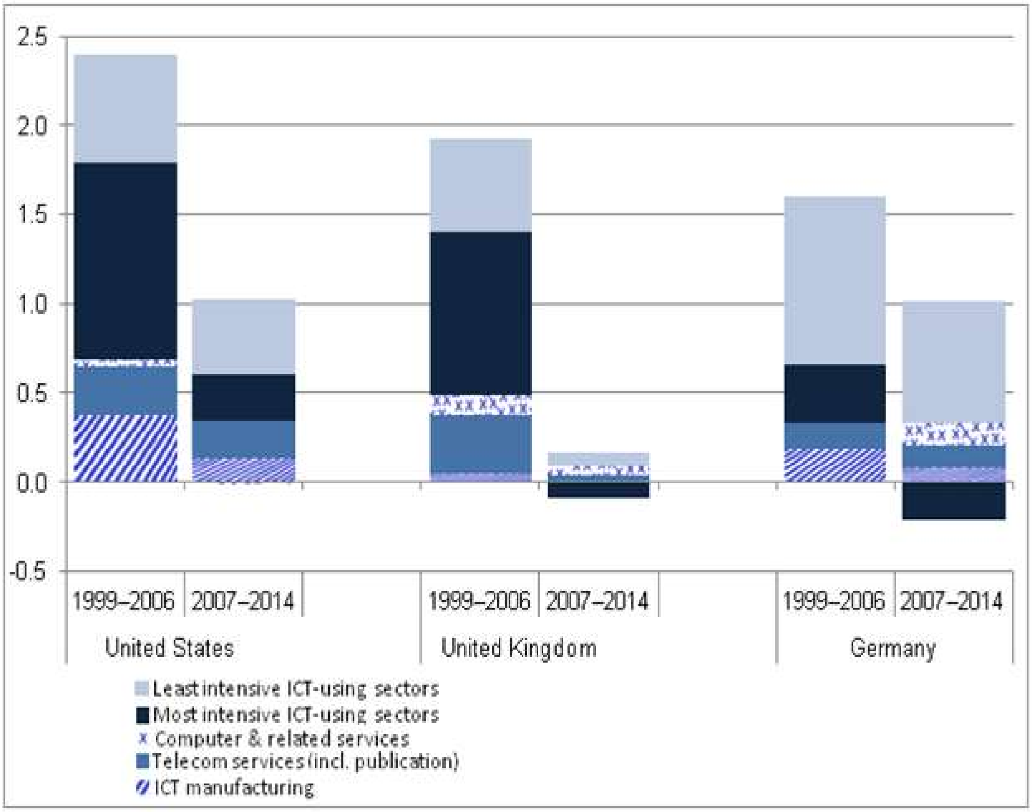
The productivity results at the sector level are even more startling when measuring the growth impact of the New Digital Economy (Chart 1). We find that the contribution of the ICT-producing sector - including ICT manufacturing (ICT hardware and telecommunication equipment), telecom services, and computer and information services - to aggregate productivity growth has weakened significantly in the United States, United Kingdom, and Germany since 2007, although it remained positive by a small margin.

What's more, we find that when looking at the top half of industries which represent the most intensive users of digital technology (measured by their purchases of ICT assets and services relative to GDP) have collectively accounted for the largest part of the slowdown in productivity growth in all three economies since 2007, namely for 60 per cent of the productivity slowdown in the United States, 66 per cent of the slowdown in Germany, and 54 per cent of the slowdown in the United Kingdom. In the United States the contribution of the most intensive ICT-using industries declined from 46 per cent to 26 per cent of aggregate productivity growth between both periods. The United Kingdom and Germany even registered negative productivity growth in the intensive ICT-using sector. The fact that ICT intensive users account for a larger part of the slowdown than less-intensive ICT users is another indication that the difficulty of absorbing the technology effectively is part of the explanation for the productivity slowdown.

A more detailed analysis of productivity performance in the United States shows that the productivity contributions of ICT-intensive and less-intensive industries are distributed rather randomly across the spectrum of fast- and slow-growing industries. Chart 2 presents a so-called

Chart 1

Contribution of ICT-Producing, Most Intensive ICT-Using and Least Intensive ICT-Using Industries to Total Economy Labour Productivity Growth, 1996–2006 and 2007–2014 (average percentage point change per year)

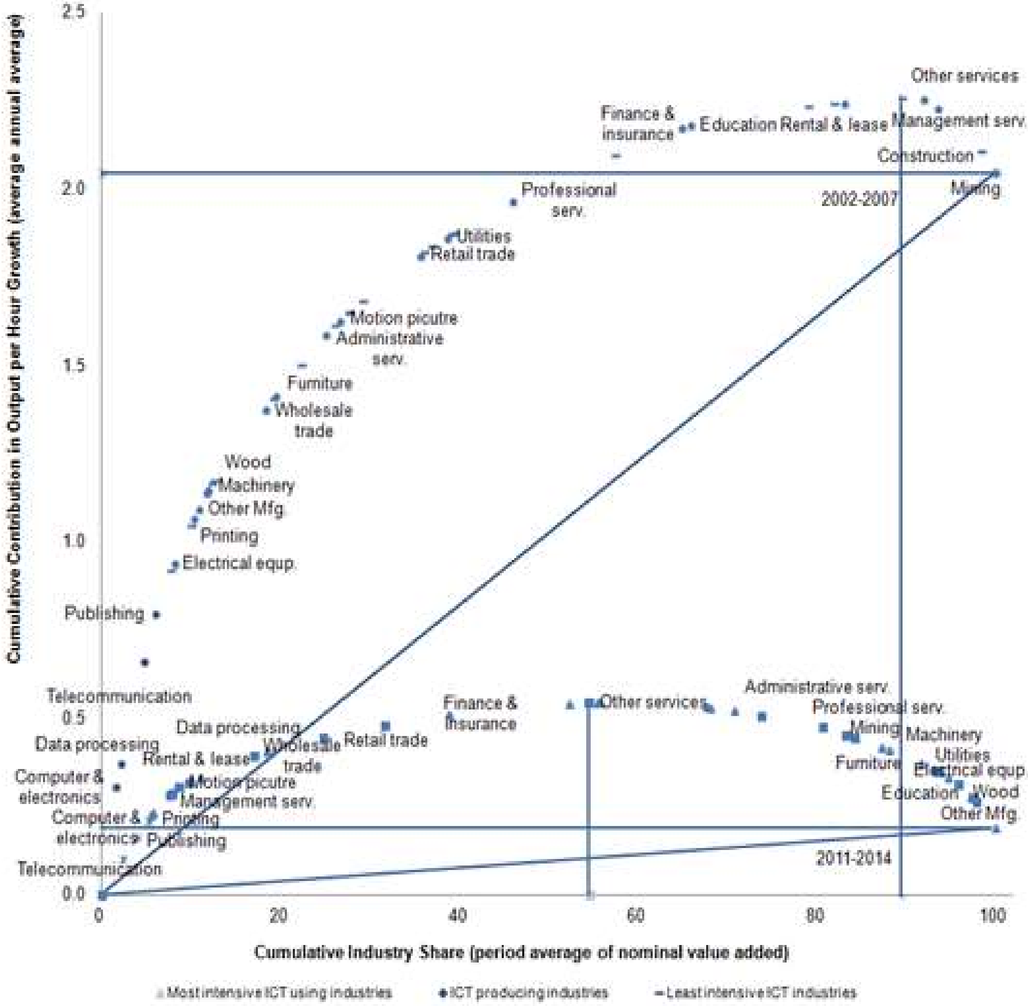


Note: "Most intensive ICT-using industries" refer to the top half of the industries with the highest share of value of ICT investment plus purchases of ICT services as a percentage of "synthetic output" (which is value added at industry level plus the intermediate use of ICT services) for each period. Least intensive ICT-using sectors refer to the bottom half of industries in terms of ICT intensity. The contribution of ICT-producing industries (which are also part of "most intensive ICT-using industries) to labour productivity growth are shown separately.
Source: van Ark *et al.* (2016)

Harberger diagram picturing the cumulative contributions of 30 industries to aggregate labour productivity growth ranked on the basis of the highest to the lowest contributions, weighted by the nominal GDP share of each sector (Harberger, 1998).

Chart 2 shows that aggregate labour productivity in the United States increased at an annual average rate of 2.1 per cent during 2002-2007 and only 0.2 per cent per year during 2011-2014. During the first period, industries account for 89.5 per cent of industry value added made positive contributions to productivity growth. Only four industries (other services, management services, construction, and mining) show negative productivity growth contributions, of which three were ICT intensive industries. During the period from 2011 to 2014 period only 55 per cent of industry value added was produced in industries with positive contributions to productivity growth. Among industries with negative productivity contributions, were ICT-intensive industries such as machinery, electrical equipment and several service industries. It seems the results are distributed randomly in terms of the positive and negative contributions

Chart 2
Cumulative Labour Productivity Growth Contributions by Industry in the United States, 2002-2007 and 2011-2014



Note: "Most intensive ICT-using industries" refer to the top half of the industries with the highest share of value of ICT investment plus purchases of ICT services as a percentage of "synthetic output" (which is value added at industry level plus the intermediate use of ICT services) for each period. Least intensive ICT industries sectors refer to the bottom half of industries in terms of ICT intensity. The contribution of ICT-producing industries (which are also part of "most intensive ICT-using industries) to labour productivity growth are shown separately.
Source: van Ark *et al.* (2016)

to productivity growth between the more and less intensive ICT-intensive industries, suggesting no impact of differences in ICT use.

ICT-producing industries, including computer and electronics, data processing and telecommunication services provided the largest positive contributions, but given the relatively small size of those industries, their impact on the aggregate is limited. However, even in ICT-producing industries, productivity growth from 2011 to 2014 was substantially below the rates of 2002-2007.

What the New Digital Economy Has Delivered So Far

Despite the disappointing productivity results from the New Digital Economy so far, there are at least three important reasons why it is premature to conclude that the New Digital Economy will not deliver on growth. We discuss these reasons in this section: 1) the ongoing rapid decline in ICT prices; 2) the rise of ICT services in business spending; and 3) the role of knowledge-based assets for ICT.

The Ongoing Rapid Decline of ICT Prices

Rapid price declines in ICT goods and services are an important manifestation of technological change and productivity growth. The dramatic acceleration in technological progress in ICT is underpinned by the strong acceleration of research and development (R&D) spending, mainly in software (Byrne and Corrado, 2016a). While the share of the digital producing sectors (ICT hardware, software and telecommunication and other ICT services) in nominal GDP of the United States has remained relatively small and stable at 6 per cent over the past two decades, the drop in prices of the assets and services (computers and peripherals, communications equipment and software) this sector produces (relative to average prices in the economy) has on average been about 7 per cent per year between the late 1980s and 2014 (Chart 3).

However, the pace by which ICT asset prices relative to aggregate prices have fallen every year, as measured by deflators from the U.S. National Income and Product Accounts, has slowed significantly over the past decade. According to calculations by Byrne and Corrado (2016a), prices for ICT assets relative to the average price decline of aggregate output (or GDP) have declined by less than 2 per cent per year from 2011 to 2015, down from 9 per cent per year from 1995 to 2005. Although improvements in cost-performance ratios in ICT have slowed since 2005, the softening price decline of ICT assets in the official statistics is not in line with the evidence from alternative estimates.

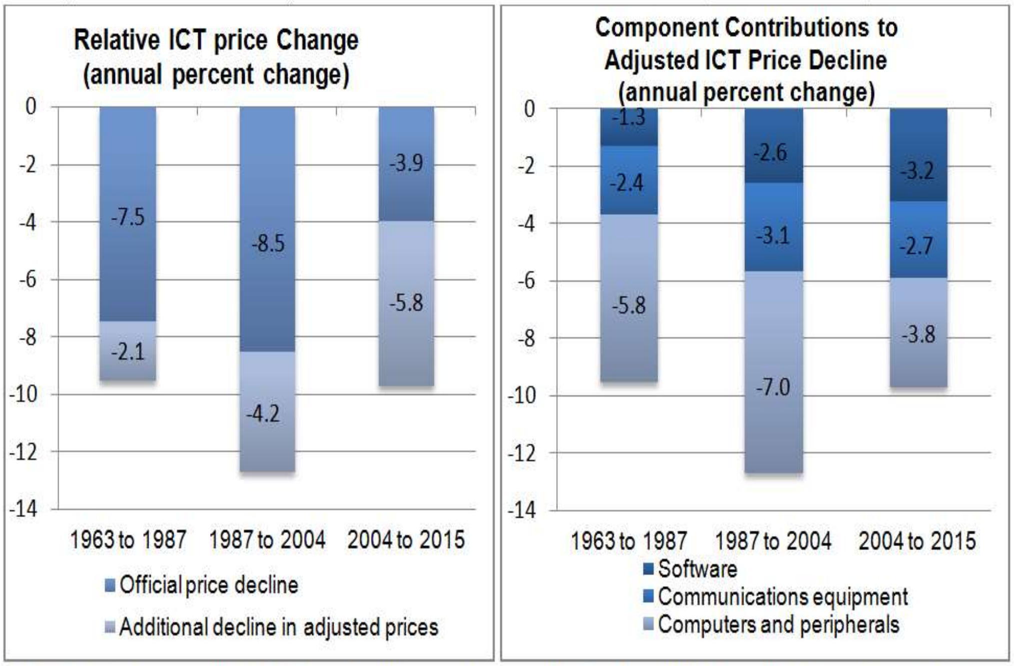
Byrne and Corrado (2016a and 2016b) have produced new price indexes for communications equipment, high-end computing equipment, and prepackaged enterprise software, which have constituted the lion's share of directly priced products in private ICT investment spending in the United States and are key enablers of technological change in the New Digital Economy. The new price series suggest that the official prices used by the US Bureau of Economic Analysis significantly understate the performance improvements of many ICT products and systems. While the pace of decline in ICT asset prices since 2004 was somewhat slower than it was in the prior two decades, it is at least on par with the experience prior to 1985 (that is, after correcting the ICT price indexes for overall inflation).

Price declines, communications equipment, and software are all faster overall than the official figures and have been well-maintained, generating a price decline of about 10 per cent per year since 2005, with a larger contribution from software and a smaller contribution from computers and peripherals (Chart 3). The new evidence suggests that the decline in prices due to the New Digital Economy has in fact continued to boost economic growth, and especially productivity growth. While the speed of these price declines is likely to peter out over time as technologies mature, improvements in cost-performance ratios for producers as well as users in the New Digital Economy will remain quite substantial for some time to come. Currently, the impact of the adjusted ICT price indexes by Byrne and Corrado on labour productivity and output growth in the United States is about 0.3 percentage points - but still not raising U.S. labour productivity much above 1 per cent on an annual basis.

Of course, these adjustments to productivity and GDP growth do not take account of the widely discussed and observed benefits the New

Chart 3

Changes in Official and Adjusted Price Indexes for ICT Investment, United States, 1963-2014



Note: Relative ICT price change is the change in the price index for ICT goods relative to the change in the price index for total GDP. Adjusted prices are official prices corrected for measurement issues. Growth rates are measured as compound growth rates.
Source: Byrne and Corrado (2016a)

Digital Economy provides to consumers. Many digital products and services can be produced at such low marginal cost that they can essentially be provided for free. For example, the benefits to the consumer from sharing spare capacity of cars (Uber) or homes (Airbnb) supported by platforms like Facebook or Google are not measured as part of GDP beyond what consumers pay for it. And the consumer utility of free content obtained from the internet is not measured at all. Hence the consumer is likely to be much better off as a result of the New Digital Economy than the statistics on GDP suggest (e.g. Aeppel (2015) and Hatzius and Dawsey (2015)).

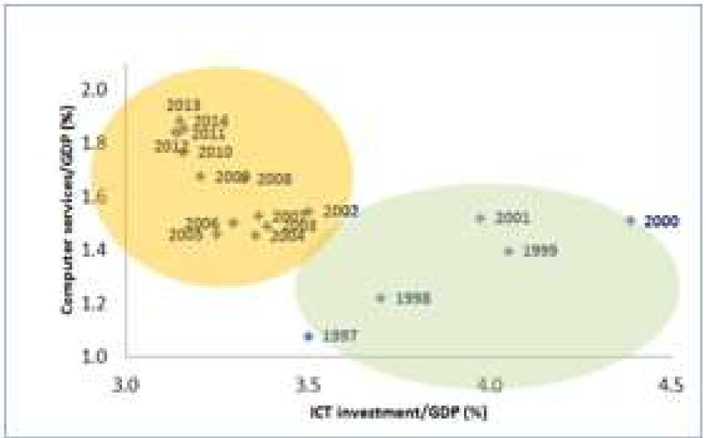
Even so some aspects of the sharing economy, such as the income consumers receive from sharing free capacity as well as the more efficient utilization of data centers by business, are already being captured in GDP through better productivity performance. But these effects add at most 0.1 percentage points to GDP growth.[4]

The statistical challenges in measuring the benefits of the New Digital Economy for the consumer are enormous - yet it should not be assumed beforehand that any adjustments will completely eliminate the slow productivity growth we are currently facing (Ahmad and Schreyer, 2016; Grömling, 2016). It should also be taken into account that some of the consumer benefits are offset by challenges for companies to be profitable. Many companies experience significant downward price pressure unless they add new unique features to their products that allow them to maintain their price margins, at least temporarily.

4 This estimate is based on Byrne, Fernald, and Reinsdorf (2016). See also Corrado and van Ark (2016), reporting a similar correction to price change for consumer internet access services.

Chart 4: Producer Purchases of Computer Services and ICT Investment as a Percent of Nominal GDP (%)

United States, 1997-2014



United Kingdom, 1997-2012

Germany, 1995-2012

Sources: US Bureau of Economic Analysis; Eurostat; German Statistical Authority; EUKLEMS; The Conference Board

The Shift from Spending on Digital Assets to Digital Services

While declining ICT prices and improved quality of digital capital assets provide a primary channel for growth in the New Digital Economy, investment in ICT as a percentage of nominal GDP has fallen substantially (Chart 4). In the United States the decline started from a peak of 4.3 per cent of nominal GDP in 2000 and gradually slowed to around 3 per cent in 2014. In the United Kingdom, ICT investment peaked in 2001 at 2.8 per cent of GDP, and slowed until 2009 after which it modestly improved. Germany's ICT investment rate peaked at 2.8 per cent of GDP in 2000, and has consistently fallen since, reaching 1.7 per cent in 2012. Much of the observed decline in the ICT investment rate is a reflection of slower growth in computers and communication equipment investment relative to GDP. Meanwhile, the share of software in GDP has remained stable in Germany, and has shown modest increases in both the United Kingdom and the United States since 2010.

In contrast to the slowdown in business investment, there has been a major rise in spending on ICT services. The latter refers to data storage and information processing services (including cloud computing), computer systems design, and other information services (including internet publishing).[5] For example, business spending on digital services (including cloud computing and other information services) relative to output has increased from 1.5 per cent in 2000 to 1.9 per cent in 2014 in the United States, from 2.2 per cent in 2000 to 3.0 per cent in 2013 in the United Kingdom, and from 1.0 per cent in 2000 and 1.8 per cent in 2012 in Germany (Chart 4). This shift from ICT assets to ICT services is having a very large impact as companies move to external service providers for their ICT infrastructure. This can range from moving data into a "private cloud" (i.e. a company's internal cloud) to accessing public cloud services to store, access, and process data.

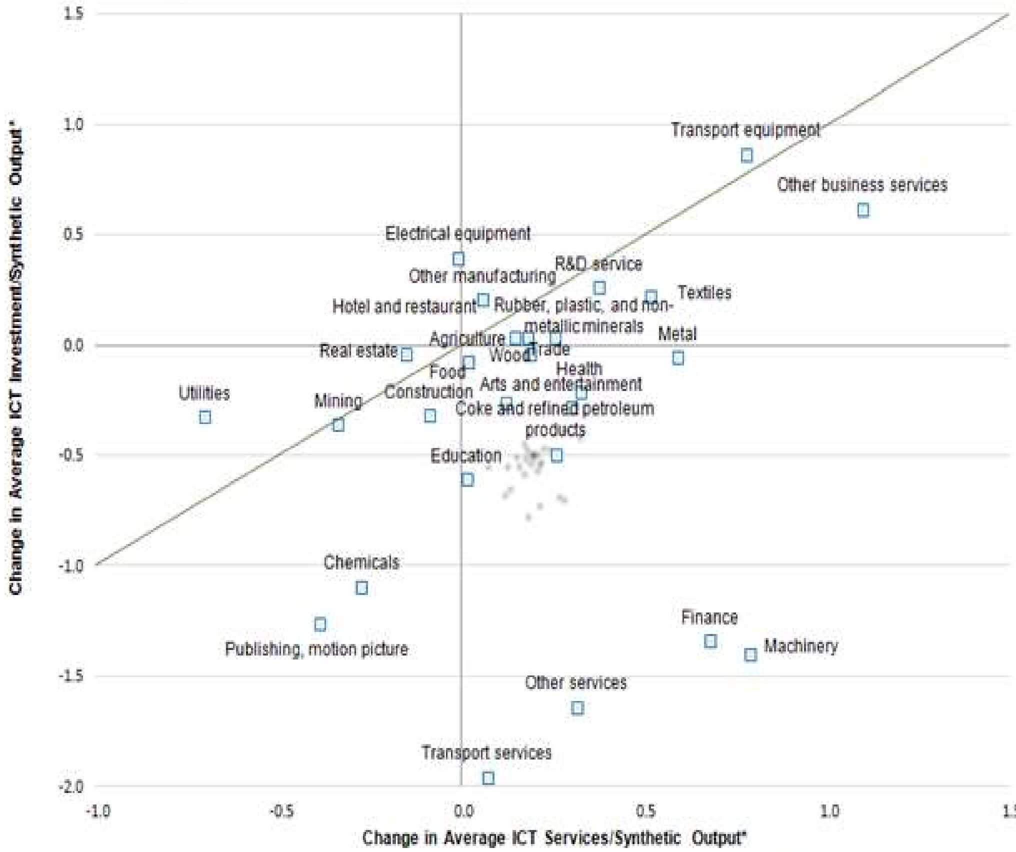
The shift from owning ICT assets to purchasing ICT services, which increases business flexibility, scalability, and utilization of data capabilities, is a widespread phenomenon across industries. Looking at data for the United States, business spending on ICT services increased much faster than spending on ICT investment in most industries, with many industries seeing a decline in the ICT investment ratio. Even industries that continued to see increased ICT investment (for example, transport equipment and other business services) have increased their ICT service use more rapidly (Chart 5). These changes allow firms to better utilize their digital data centers and to save directly on ICT expenses and on related costs such as energy, labour, and maintenance. The savings improve companies' resource allocation and efficiency, and can ultimately contribute to the economy's overall productivity performance.

While official measures are not available, some private sector estimates suggest that price declines for ICT services have been even more dramatic than for ICT investment. For example, one estimate suggests that the US bandwidth cost-performance ratio (dollar value of megabits per second) has fallen more than 25 per cent per year since 1999 - a pace near that of the historical cost-performance ratios commonly reported for computers (Hagel *et al.*, 2013). Cloud computing and storage prices have also been falling very rapidly in constant-quality terms. For example, one source suggests that Loudcloud,

5 More precisely, computer services refer to the following detailed industries in the North American Industry Classification System (NAICS): data processing, hosting, and related information services (NAICS 51820 and 51913) and computer systems design services and related computer services (NAICS 54152, 54153, and 54159).

Chart 5

Change in ICT Investment Intensity and ICT Services Intensity in US Industries Between 1999-2006 and 2007–2014



* Annual average for the period 2007–2014 minus the annual average for the period 1999–2006

Note: ICT investment consists of investment in software, hardware, and communication equipment; ICT services consist of computer systems design and related services as well as data processing, internet publishing, and other information services. Synthetic output is defined as the sum of industry value added and the intermediate use of ICT services. ICT-producing industries are excluded from this chart.

Sources: US Bureau of Economic Analysis; The Conference Board

which is claimed to be one of the first cloud computing companies, saw a decline in cost for a customer running a basic internet application from $150,000 U.S. per month in 2000 to $1,500 U.S. per month 10 years later (Andreessen, 2011). These figures imply a price drop of more than 30 per cent per year for cloud services during the 2000s, a pace of change that appears to have continued in recent years.[6]

Still, despite those impressive changes, the shift toward full usage of digital services is incomplete as yet. A recent survey of more than 550 companies in Europe and the United States suggests only a modest uptake on one major usage of digital services, which is "big data" analytics.[7] Only 28 per cent of companies in North America and 16 per cent in Europe had undertaken big data initiatives as part of their business

6 In March 2014 Google announced price cuts for its cloud computing services and storage by 30 per cent, only to be followed about one year later by further cuts in the 20 to 30 per cent range. See Lardinois (2014) and Yegulalp (2015) for reports on these changes.

processes in 2015. Another 25 per cent of companies in North America and 23 per cent in Europe had implemented a big data initiative as a pilot project. Hence about half of companies surveyed had not yet undertaken any big data initiative. Strikingly, the study also found that manufacturing companies were lagging in applying big data analytics projects in regular business processes by 14 percentage points relative to the retail sector (27 per cent versus 13 per cent of companies in each sector).

The Role of Knowledge-based Assets for ICT

There are various reasons why the rapid decline in ICT prices and the shift to ICT services is still facing impediments in terms of its impact on growth. Those range from external factors related to slower economic growth to factors internal to the firm. For example, there are multiple barriers to the use of big data analytics including IT capabilities, data privacy issues, analytical skills of the workforce, and companies' organizational adaptability.[8] Raising productivity by shifting inputs from ICT assets to ICT services strongly benefits from the use of critical knowledge-based assets (KBA) - often also referred to as intangible capital.

Knowledge-based capital consists of the intangible assets resulting from firms' investments in software, R&D, other innovative property (e.g. product and services design), and economic competencies (e.g. investments in firm-specific training and organizational change). In fact, a key takeaway from previous microeconomic studies of productivity change within firms is that these economic competencies investments are part of a complex link between firm-level IT adoption and productivity growth. In addition, increased collaboration and interaction within firms are having a large impact on several measures of firm performance, including R&D and sales (Brynjolfsson and Hitt, 2000; Brynjolfsson and Hitt, 2003).

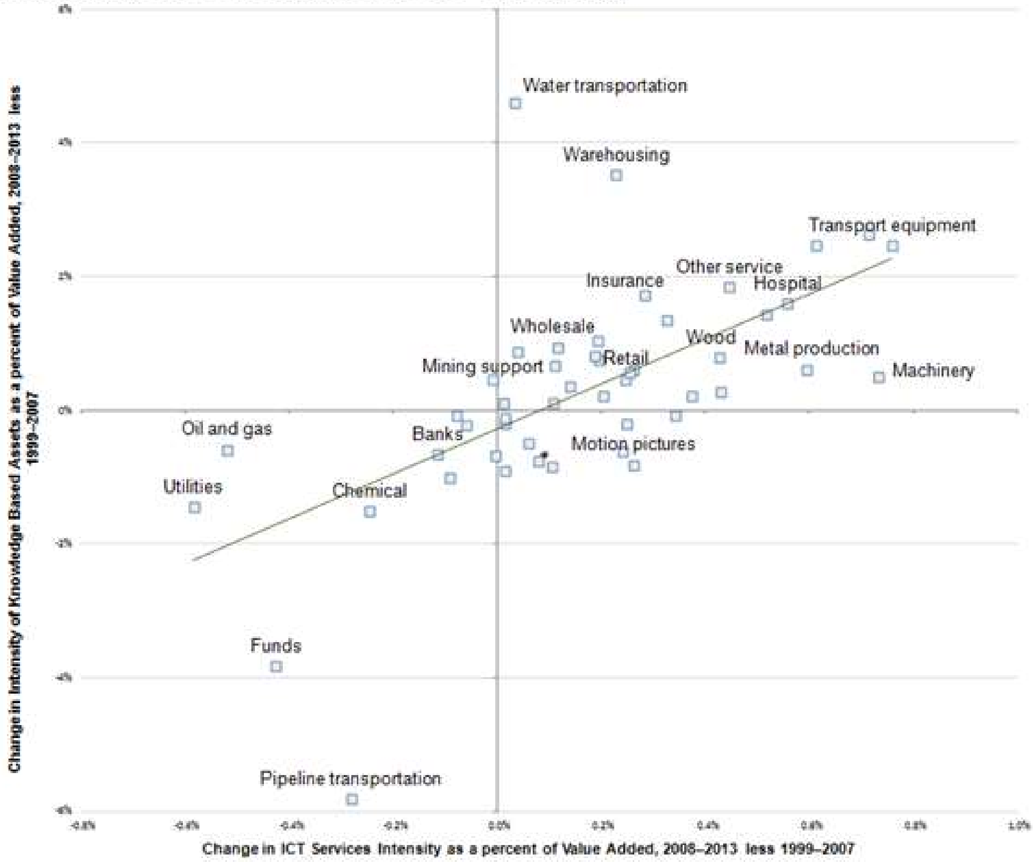
During the Great Recession of 2008-2009, the pace of KBA accumulation somewhat weakened. This development may have reduced the impact of digital technology for productivity growth. However, since 2010 investment growth in most KBA has recovered strongly and has been faster than that of overall investment in machinery, equipment and structures. In the United States, the combined business spending on design, workforce training, and organizational innovations kept about the same pace as the rise in business R&D. In the United Kingdom, whose economy is strongly services-based with financial and business services absorbing large amounts of spending on business competencies, combined business spending on design far outstripped the R&D increase. Only in Germany, where manufacturing is more dominant, was R&D growth stronger than spending on KBA - and the growth gap between the two even increased somewhat (van Ark *et al.*, 2016: 33).

There is a strong complementarity between business spending on KBA and ICT services. For the United States both manufacturing (including transportation equipment, machinery, and metal products) and services sectors (such as transportation, retail, and insurance) have seen strong positive relationships in the

7 Bange *et al.* (2015:9) use the following definition of "big data": "Big data describes the methods and technologies for the highly scalable loading, storage and analysis of polystructured data. Big data technology can help companies to manage large data volumes, complex analysis, and real-time integration of data from a variety of data structures and sources."

8 For example, Bange *et al.* (2015) finds that 49 per cent of companies in North America and Europe report inadequate analytical know-how in the company to make better use of big data technologies and analysis, and 34 per cent responded that company processes are not mature enough for the use of big data technologies.

Chart 6
Changes in Knowledge-Based Assets and ICT Services Intensity by Industry
United States, 2008–2013 Relative to the 1997–2007 Average



Note: ICT services intensity is defined as spending on ICT services relative to GDP during the New Digital Economy period (2008–2013) compared to its rate in the prior period (1997–2007). Knowledge-based assets refer to design and economic competencies such as brand, organizational structure, and firm-specific employee training. ICT-producing industries and outlier industry pairs are not plotted. Outlier industries include apparel, leather and allied product manufacturing, securities, commodity contracts and investments, rental and leasing services and lessors of intangible assets, and management of companies.
Sources: The Conference Board for SPINTAN (EU FP7 project under grant agreement No. 612774); INTAN-Invest; and elaboration of data from the US Bureau of Economic Analysis

rise of KBA and ICT services intensities between 1997-2007 and 2008-2013 (Chart 6). While correlation is no proof of cause, it is plausible to assume that the increase in knowledge-based assets works in tandem with ICT services for producer innovation, as it repeats historical patterns that have been well documented for the Old Digital Economy in relation to ICT capital (Corrado *et al.*, 2014).

From the Installation Phase to the Deployment Phase of the New Digital Economy

This article argues that one paradox of the New Digital Economy as yet remains unresolved: as the economy seems to be digitizing at an unprecedented pace, why are we not seeing much faster economic growth and productivity increases? Why are many businesses not seeing a major impact from digital technology on revenue and profits, while some seem to be running ahead of everyone else? Why have not wages

Figure 1
Installation Phase versus Deployment Phase in the New Digital Economy

Source: Based on Carlota Perez, Technological Revolution and Financial Capital: The Dynamics of Bubbles and Golden Ages (Cheltenham, United Kingdom: Edward Elgar Publishing Limited), 2002.

gone up faster, especially for high-skilled workers who are in great demand?

Are we at the doorstep of a new transformative era for business that can lead to explosive growth due to the latest trends in digitization? Or could it be that the effects of the New Digital Economy will be less dramatic than expected and unable to reverse the current sluggish growth path?

Using a typical lifecycle model of innovation and based on historical experiences, one can distinguish between the "installation phase" and the "deployment phase" in any new general purpose technology, as shown in Figure 1.[9] The installation phase is characterized by a much greater interest in the new technology as early application cases emerge. Research and development and other innovation expenses are increasing as organizations access new ICT assets and services to develop product and service innovations. Typically first movers, whether these are particular companies, sectors, or industries, move ahead of their followers in terms of adoption of the technology and the speed with which they see results in the form of productivity gains or new products and services. The success cases during the installation phase often represent the so-called mushroom effects scattered around in a field with companies failing as well as many organizations and sectors that remain unaffected (Harberger, 1998). Toward the end of the installation phase, an economy often experiences a period of frenzy, with expectations overshooting the potential for growth, followed by a bubble burst. This frenzy period can often provide a cleanup of overinvestment, followed by the deployment phase. During this phase the technology will play out as a true General Pur-

9 For a detailed review of the concepts of installation and deployment phases in technology as well as how one period evolves into the other - often interrupted by a frenzy period and a crisis - including an historical review, see Perez (2002). For a recent application, see Neumann (2015).

pose Technology (GPT) in all its aspects: ubiquitous use and widespread adaptation of technology in multiple applications, and significant real cost reductions leading to lower prices as well as market scale for the new products and services.

This article has argued that there are good reasons to believe that the New Digital Economy is still in the installation phase producing only random and localized gains in productivity in certain industries and geographies. And while increases in knowledge-based assets in selected industries are positively related to the shift toward greater use of ICT services, there are no signs as yet that collectively they have contributed to productivity growth.

One can possibly draw an historical parallel between the current situation of weak productivity growth and rapid technological change and the first half of the 1990s, when these two phenomena were also observed. The term 'productivity paradox'was coined to describe this earlier situation, which resolved itself with a spurt of ICT-fueled productivity growth between 1995 and 2004 (van Ark *et al.*, 2003). History may repeat itself.

This raises the question as to where, when, and how the benefits of the New Digital Economy will play out. In other words, with regard to the rapid technological change-slow growth conundrum, ultimately something will have to give. One possibility is that the large efforts made through business investment and spending are not going to pay off in terms of much more revenue growth, especially if aggregate demand and investment remain weak sources of growth. While there will still be opportunities for growth from the New Digital Economy, they may be much narrower in scale or scope than often assumed and the returns on the aggregate investment may be lower. Also some of the gains may more likely arise from digitally-based improvements in business processes and higher productivity, leading to tangible cost reductions, rather than from higher revenue growth.

The other possibility is that economic growth, and especially productivity growth, will eventually become much stronger as businesses double down on making the technologies work better despite some headwinds, by focusing on the revenue opportunities that will likely arise. Some headwinds to digital transformation may arise from a non-conducive business environment, including unfavorable regulatory policies, a lack of skilled workers, or difficulties in obtaining funding for startups or small enterprises who aim to develop new innovations in the New Digital Economy. But they may also come from challenges within the firm, such as the ability to effectively combine new technologies with human capital and critical knowledge-based assets.

While we do not expect large aggregate growth effects from the New Digital Economy any time soon, our analysis suggests that even in a slow growth environment there are significant benefits in terms of productivity growth provided companies and economies focus on the following (van Ark *et al.* 2016):

- Take advantage of ongoing rapid price declines in information and communication technology (ICT) assets and services to obtain significant cost reductions;
- Leverage the shift from investment in ICT assets to purchased digital services to increase firms' flexibility in raising productivity and speeding up the bringing to market of new products and services;
- Create key knowledge-based assets (product and services design, workforce training, and organizational improvements) to strengthen innovative capabilities;
- Assess and manage different degrees of talent shortages among digital workers and tech-savvy workers;

- Utilize local innovation ecosystems by taking advantage of access to talent, partnerships, and shared services; and,
- Create agility and resiliency to anticipate and respond to the disruptive impact of new technology.

References

Aeppel, Timothy (2015) "Silicon Valley Doesn't Believe US Productivity is Down," *Wall Street Journal*, July 17, http://www.wsj.com/articles/silicon-valley-doesnt-believe-u-s-productivity-is-down-1437100700.

Ahmad, Nadim and Paul Schreyer (2016) "Are GDP and Productivity Measures Up to the Challenges of the Digital Economy?" *International Productivity Monitor*, No. 30, Spring. pp. 4-27, http://www.csls.ca/ipm/30/ahmadandschreyer.pdf.

Andreessen, Mark (2011) "Why Software Is Eating the World," *The Wall Street Journal*, August 20.

Bange, Carsten, Timm Grosser, and Nikolai Janoschek (2015) "Big Data Use Cases: Getting Real on Data Monetization," Business Application Research Center (BARC).

Brynjolfsson, Erik and Lorin M. Hitt (2000) "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *Journal of Economic Perspectives*, Vol. 14, No. 4, pp. 23-28.

Brynjolfsson, Erik and Lorin M. Hitt (2003) "Computing Productivity: Firm-level Evidence," *Review of Economics and Statistics*, Vol. 85, No. 4, pp. 793-808.

Brynjolfsson, Eric and Andrew McAfee (2011) *Race against the Machine - How the Digital Revolution Is Accelerating Innovation, Driving Productivity, and Irreversibly Transforming Employment and the Economy* (Lexington, MA: Digital Frontier Press).

Byrne, David and Carol Corrado, (2016a) "ICT Prices and ICT Services: What Do They Tell You about Productivity and Technology?" Economics Program Working Paper Series, No. 16-05, The Conference Board, July.

Byrne, David and Carol Corrado (2016b) "ICT Asset Prices: Marshaling Evidence into New Measures," Economics Program Working Paper Series, No. 16-06, The Conference Board, July.

Byrne, David, John Fernald, and Marshall Reinsdorf (2016) "Does the United States have a Productivity Slowdown or a Measurement Problem?" *Brookings Papers on Economic Activity*, March.

Corrado, Carol and Bart van Ark (2016) "The Internet and Productivity," in *Handbook on the Economics of the Internet*, eds. Johannes M. Bauer and Michael Latzer (Cheltenham, United Kingdom: Edward Elgar Publishing).

Corrado, Carol, Jonathan Haskel, and Cecilia Jona-Lasinio (2014) "Knowledge Spillovers, ICT, and Productivity Growth," *Economics Program Working Paper Series* No. 14-02, The Conference Board, May.

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

Gordon, Robert J. (2016b) "Comments on Daniel E. Sichel's Review Article on *The Rise and Fall of American Growth*," *International Productivity Monitor*, No. 31, pp. 63-67, Fall, http://www.csls.ca/ipm/31/gordon.pdf.

Grömling, Michael (2016) "The Digital Revolution - New Challenges for National Accounting?" *World Economics*, January-March, pp. 1-13.

Hagel, John, John Seely Brown, Tamara Samoylova, and Michael Lui (2013) "From Exponential Technologies to Exponential Innovation: Report 2 of the 2013 Shift Index Series," Deloitte University Press, Deloitte Center for the Edge.

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

Hatzius, Jan and Kris Dawsey (2015) "Doing the Sums on Productivity Paradox v2.0," Goldman Sachs US Economics Analyst, Vol. 15, No. 30, July 24.

Lardinois, Frederic (2014)"Google Announces Massive Price Drops for Its Cloud Computing Services and Storage, Introduces Sustained-Use Discounts," *Tech Crunch*, March 25.

Ford, Martin (2015) *The Rise of Robots: Technology and the Threat of a Jobless Future* (New York: Basic Books).

Neumann, Jerry (2015) "The Deployment Age," *Reaction Wheel*, Blog, October 14.

Perez, Carlota (2002) *Technological Revolution and Financial Capital: The Dynamics of Bubbles and Golden Ages* (Cheltenham, United Kingdom: Edward Elgar Publishing).

Sichel, Daniel E. (2016) "Two Books for the Price of One: Review Article of *The Rise and Fall of American Growth* by Robert J. Gordon," *International Productivity Monitor*, No. 31, Fall, pp. 57-62, http://www.csls.ca/ipm/31/sichel.pdf.

Summers, Lawrence (2016) "The Age of Secular Stagnation: What It Is and What to Do about It," *Foreign Affairs*, March/April, pp. 2-9.

Teulings, Coen and Richard Baldwin (2014) "Secular Stagnation: Facts, Causes, and Cures," *VoxEU*, Centre for Economic Policy Research, London.

van Ark, Bart (2015) "Blaming the Productivity Slowdown on Measurement Issues Takes our Eyes off the Ball", July 22, http://tcbblogs.org/economy/2015/07/22/blaming-the-productivity-slowdown-on-measurement-issues-takes-our-eyes-off-the-ball.

van Ark, Bart (2016) "Global Economic Outlook 2017: Bucking the Trend, Overcoming Uncertainty, Shocks and Disruption with Qualitative Growth," The Conference Board, November.

van Ark, Bart, Robert Inklaar and Robert H. McGuckin (2003) "The Contribution of ICT-Producing and Using Industries to Productivity Growth: A Comparison of Canada, Europe and the United States," *International Productivity Monitor*, No. 6, Spring, pp. 56-63, http://www.csls.ca/ipm/6/vanarketal-e.pdf.

van Ark, Bart, Ataman Ozyildirim, Prajakta Bhide, Elizabeth Crofoot, Abdul Erumban, and Gad Levanon (2015) "Prioritizing Productivity to Drive Growth, Profitability, and Competitiveness," The Conference Board, June.

van Ark, Bart, Abdul Erumban, Carol Corrado, and Gad Levanon (2016) *Navigating the Digital Economy: Driving Digital Growth and Productivity from Installation to Deployment*, The Conference Board, May.

Yegulalp, Serdar (2015)"Google One-downs Amazon with New Cloud Price Cuts," *Infoworld Tech Watch*, May 18.