How ICT Can Restore Lagging European Productivity Growth

BY ROBERT D. ATKINSON | OCTOBER 2018

Raising productivity growth rates will be crucial for Europe to prosper. And a key factor in engineering such a turnaround will be supporting the widespread adoption of information and communication technologies by organizations.

Notwithstanding the emergence of artificial intelligence (AI), robotics, and the Internet of Things (IOT), European productivity growth has slowed, and continues to lag U.S. growth.[1] Since the financial crisis, labor productivity in the 28 EU member states has grown just 0.7 percent annually. At this rate, it will take a century for Europe's per capita incomes to double. No wonder there is political unrest across the continent. And while Europe decreased the productivity gap with the United States before 1995, since then, the gap has only widened. Reversing that trend is critical if Europe is going to be able to effectively cope with its demographic challenges, particularly a rapidly aging population, and be able to more effectively compete in global markets. To do that it needs more ubiquitous use—as distinct from production—of information and communication technologies (ICTs) by all organizations (for-profit, nonprofit, and government) throughout all of Europe.

Increasing productivity is how countries raise per capita income. It should therefore be no surprise that over two decades of lackluster productivity growth have left European incomes stagnant, many European companies uncompetitive, and European government finances shaky. Only one EU-15 country, Ireland, has managed productivity growth rates that exceeded those of the United States since 1995. Given the demographic challenges and increasing international competition Europe faces in the coming decades, it is crucial Europe find a way to reverse these growth trends.

Scholarly evidence strongly suggests that increased ICT adoption, particularly the technologies underpinning the "next production revolution" (AI, IOT, and robotics) and the transformative change ICT can bring to organizations, is a key component of fixing Europe's lagging productivity. ICT is a general-purpose technology (GPT) that reshapes systems of production and distribution, with wide-ranging effects throughout entire economies.

Compared with the United States, Europe has had far smaller productivity gains from ICT. Although the contribution of ICT varies between European countries—only two Scandinavian nations (Denmark and Sweden) have gained more from ICT than the United States—other EU nations have been able to reap fewer benefits. This variation between countries, along with variation at the industry and firm levels, makes clear, however, that those countries, industries, and firms that do invest in and use more ICT reap significant benefits.

Europe's more limited productivity gains from ICT initially presented a puzzle, because in many ways Europe appeared to be well suited to gain from new technologies. Over time, however, the reasons for Europe's limited gains appear to have been identified. The primary proximate cause is simply lower levels of capital investment in ICT. Since the 1990s, European countries have significantly lagged behind the United States in levels of ICT investment, both as percent of total fixed capital investment and as percent of GDP. And this is true not just of the ICT-producing sector itself. ICT-using sectors, primarily the service sector, have invested less in ICT than their counterparts in the United States. Productivity in European private-sector services grew less than half as fast as it did in the United States between 2006 and 2016, because the positive effects of ICT production didn't spill over into use.[2]

There are four primary reasons for Europe's failure to invest in and gain from ICT. First, regulation within product, labor, and land markets limits possible business models, raises the cost of ICT investment, and slows down market forces that can push firms to adopt more productive practices. For example, privacy regulations reduce the effectiveness of online advertising, which is a reason why, as a share of GDP, digital advertising spending was three times higher in the United States than in Europe in 2017. Labor regulations also limit firms' ability to use ICT to reengineer production processes in ways that reduce head count.

Second, EU consumption taxes on ICT products are higher, which lowers consumer and business adoption of ICT.[3] Corporate tax policies may play a role as well, as depreciation rates for ICT capital investments are generally less generous than in the United States.

Third, European businesses have a harder time reaching larger markets that provide greater economies of scale. Notwithstanding the European Commission's Digital Single Market initiative, markets are still fragmented. That fragmentation limits the potential size of markets, which in turn makes it harder for firms to achieve economies of scale from ICT investments. This is critical because ICT enables firms to increase sales by capturing larger markets.[4] Moreover, Europe's very high proportion of small firms makes it hard for firms to surmount the high fixed costs of many ICT investments, limiting ICT use and productivity in small firms. And by favoring small firms over large ones, EU tax, spending, and regulatory policies have artificially kept firm sizes smaller than they would otherwise be, leading to a reduction in both ICT investment and productivity.

Another faction is management styles. Research has shown that getting the full potential from ICT investments requires organizational redesign, and that U.S. firms have been better than EU firms at employing management techniques that can facilitate such transformation.[5]

Although European productivity growth has slowed, both in absolute terms and when compared with the United States, there should be reason for measured optimism. First, the next production revolution, (e.g., robotics, AI, autonomous systems, IOT), while still too nascent to be seen in today's productivity statistics, is likely to begin to show up statistically in the next 5 to 10 years. Ensuring EU policies support, rather than hinder, the ability of organizations to deploy these technologies will be important. This will, among other things, require eschewing the precautionary principle. But beyond that, Europe needs to make productivity improvement the centerpiece of economic policy, and not give into what are fundamentally irrational fears that technology will lead to higher unemployment.[6]

Europe needs to make productivity improvement the centerpiece of economic policy, and not give into what are fundamentally irrational fears that technology will lead to higher unemployment.

Second, Europe needs to focus on raising productivity in industries where productivity growth has been slow, such as retail and professional services, by encouraging the adoption of ICT. This focus should be primarily on ICT-using sectors because ICT-producing sectors alone are unlikely to provide significant productivity increases to the economy without the adoption of ICT in other sectors. In addition, actions that encourage ICT-producing sectors can sometimes hurt ICT-using sectors, such as when protective tariffs, limits on cross-border data flows, or other actions that bias the market toward local ICT producers raise ICT prices for ICT-using industries.

Third, Europe can actively assist in the digital transformation of industries by creating the right conditions for ICT investment and adoption. The EU and national governments can do this through their own procurement and adoption of ICT products and services—and can also play a proactive role in addressing network externalities that exist in many sectors, such as health care, education, and transportation.

Fourth, tax and trade policies provide important levers Europe can use to promote ICT investment. By minimizing taxes on ICT investment, policymakers can encourage ICT adoption in firms. Investment tax incentives are particularly important because while ICT investment provides large benefits for the broader economy, the nature of these benefits makes them hard for any single firm to capture; therefore, firms tend to underinvest in ICT. Trade policy can also play a role, particularly by enabling cross-border data flows, not just within Europe but between Europe and other nations. As most industries become digital, more and more firms need to move data across borders seamlessly.[7]

Fifth, Europe should reduce preferences for small businesses. The high percentage of small firms in Europe, and in Mediterranean countries in particular, holds back productivity. "gazelle" firms that start small and grow quickly are important, but most small businesses are not innovative and have lower rates of ICT investment and productivity.[8] Most of Europe's significant array of tax, regulatory, and spending programs to help small businesses hurt ICT adoption.

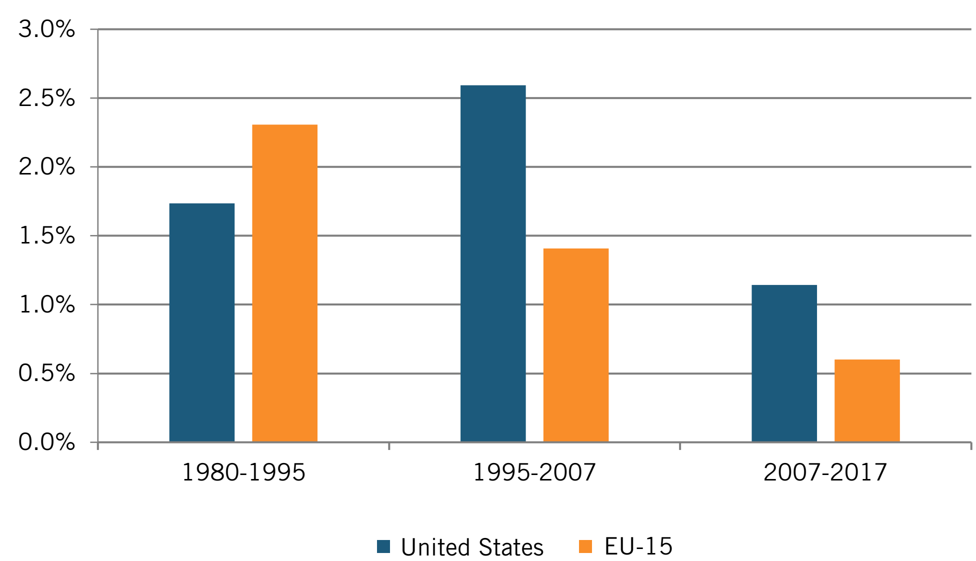
Finally, Europe needs to be vigilant about "doing no harm." This is particularly important as the technologies associated with the next production revolution are beginning to be improved and more widely deployed. Europe needs to find ways to address legitimate concerns around digital policy issues without reducing innovation, increasing costs, or reducing ICT adoption.

This report examines EU and U.S. productivity trends; discusses why higher productivity is critical for the future of Europe; examines both the relationship between ICT and productivity in the United States and Europe, and major causes of EU lag; and lays out in further detail the six key policy principles for attaining EU digital prosperity.

EU AND U.S. PRODUCTIVITY TRENDS

For the postwar period between 1950 and 1995, productivity grew faster annually throughout Europe (by 3.1 percent in France, Germany, Belgium, Italy, and the Netherlands) than in the United States (by 2.1 percent). Yet, after 1995, the trend reversed. U.S. labor productivity growth averaged 1.7 percent per year from 1980 to 1995, rose to 2.6 percent from 1995 through 2007, and then slowed to 1.1 percent between 2007 and 2017.[9] Annual EU-15 productivity growth declined from 2.3 percent per year from 1980 to 1995 to 1.4 percent between 1995 and 2007 to just 0.6 percent since then (figure 1).[10]

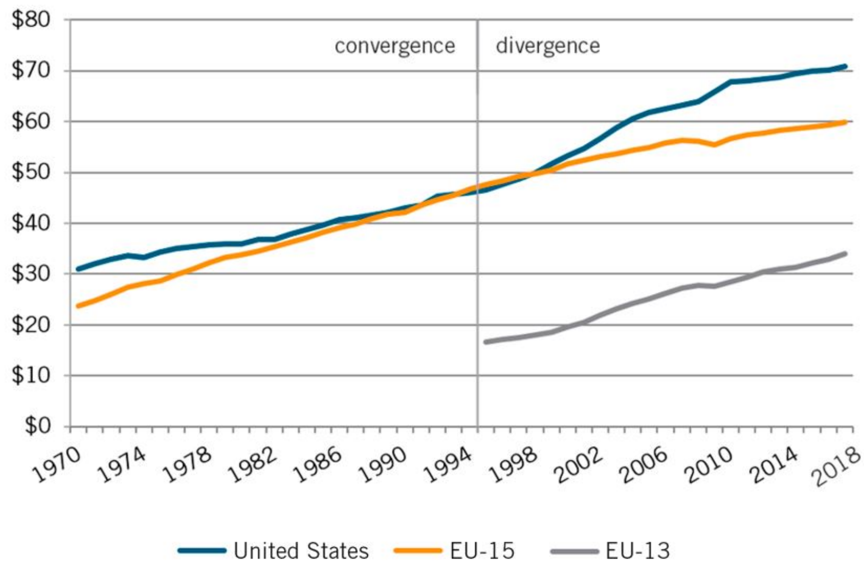
Figure 1: EU-15 and U.S. average annual labor productivity growth, 1980–2017[11]



As a result, the labor productivity gap in the EU-15 relative to the United States widened by 18 percentage points between 1995 and 2018, from 2 percent greater to 16 percent less (figure 2).[12] And while EU-13 productivity growth has been faster than U.S. growth (3.3 percent versus 1.9 percent from 1995 to 2018), their productivity levels were 52 percent lower than U.S. levels in 2018; and at current growth rates, EU-13 will need 50 years to close that productivity gap (figure 3). Overall, EU-28 productivity levels are 24 percent lower than U.S. levels.[13]

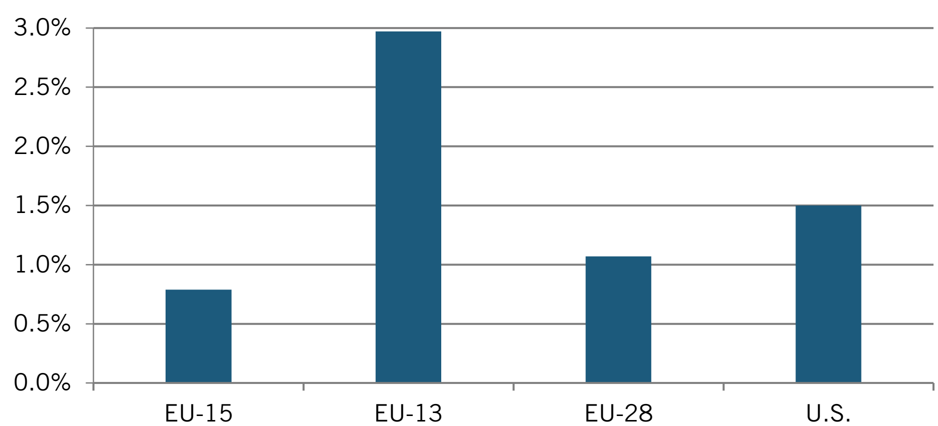
The labor productivity gap in the EU-15 relative to the United States widened by 18 percentage points between 1995 and 2018, from 2 percent greater to 16 percent less than U.S. levels.

Figure 2: EU-15, EU-13, and U.S. labor productivity growth trends, 1970–2018 (GDP per hour worked, U.S. dollars, purchasing power parity)[14]



The diverging productivity trends also reflect important industry-level differences. Of eight major industry groups (i.e., manufacturing, construction, etc.) U.S. productivity growth since 2001 has been more broadly based: four out of eight U.S. industries (agriculture, mining and utilities, construction, and financial services) saw higher productivity from 2009 to 2016, compared with just two out of eight EU industries (construction and professional services).[15]

Figure 3: EU-15, EU-13, EU-28, and U.S. average annual labor productivity growth, 2002–2017[16]



Within the EU, the performance of individual nations has varied significantly, and trends leading up to and after 2007 have been mixed. Ireland is the sole EU-15 nation to converge with U.S. labor productivity over both the 1997–2007 period and the 2007–2017 period.[17] As a result, the Irish productivity differential with the U.S. economy went from 9 percent less in 1997 to 16 percent more in 2017 (table 1). In 1997, Irish productivity was $44 per hour worked as compared with U.S. productivity of $49 per hours worked; but by 2017, Irish productivity increased to $82 per hour worked as compared with $71 per hour worked in the United States.

Table 1: EU-15 productivity growth relative to the United States[18]

		2004–2013	
		Diverging	Converging
1995 –2004	Converging	Finland Greece Sweden United Kingdom	Ireland
	Diverging	Belgium Denmark France Germany Italy Luxembourg The Netherlands Portugal	Austria Spain

No other nation reduced the productivity gap with the United States in the first period (1997–2007), and only Spain reduced it in the more recent period (2007–2017), in part because of a reduction in hours worked. Belgium, Finland, France, Greece, Italy, Luxemburg, the Netherlands, and the U.K. all grew their productivity at less than half the rate of U.S. growth between 2007 and 2017.

Most EU-13 countries have had more robust productivity growth rates. As shown in table 2, most grew faster than the United States in both periods between 1997 and 2017. Only Cyprus and Malta lost ground in both periods. However, the EU-13 countries constitute less than 12 percent of EU's GDP, and are only 58 percent as productive as EU-15 nations (figure 4 and figure 5).[19]

If the United States and EU-15 had swapped productivity growth rates from 1995 to 2013, EU GDP would be €2.2 trillion larger than the United States, instead of €1.6 trillion smaller.

Table 2: EU-15 productivity growth relative to the United States[20]

		2007–2017	
		Diverging	Converging
1997–2007	Converging	Czech Republic Hungary Slovenia	Bulgaria Estonia Latvia Lithuania Malta Poland Romania Slovakia
	Diverging	Cyprus	Croatia

Figure 4: EU-13 productivity percent growth rate relative to the United States (area of circle is relative size of country GDP)[21]

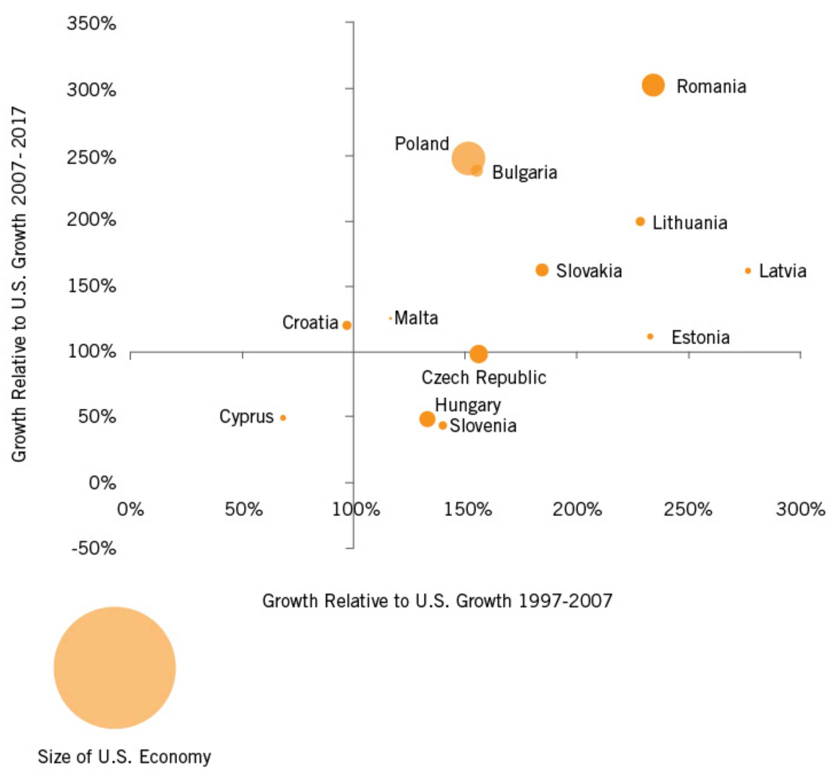
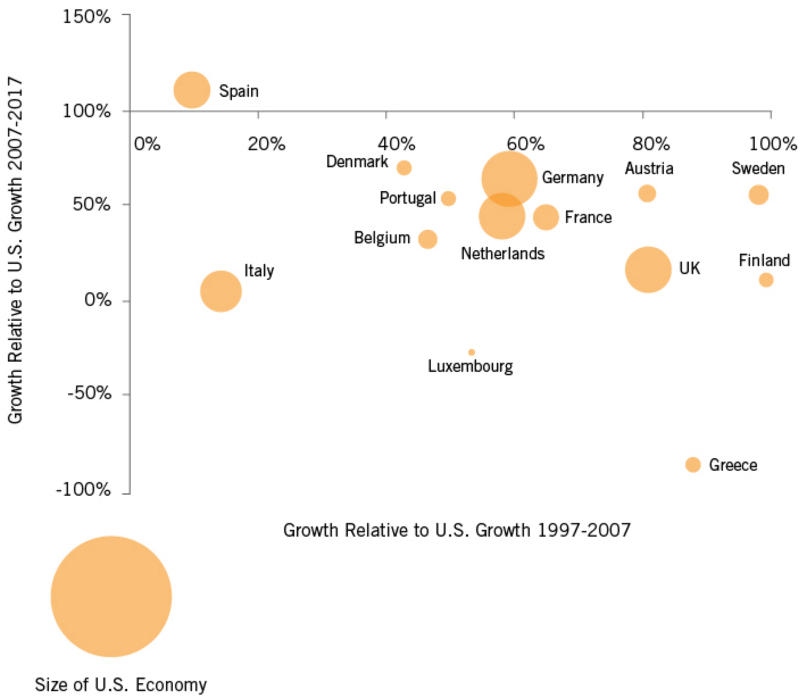


Figure 5: EU-15 productivity percent growth rate relative to the United States (area of circle is relative size of country GDP)[22]



WHY EUROPE NEEDS TO ACCELERATE PRODUCTIVITY GROWTH

Higher productivity is the sine qua non of economic growth.[23] To see why, consider that if the EU-15 nations had maintained the productivity growth rate they enjoyed from 1980 to 1995 through to 2017 their annual GDP would be 31 percent larger today (in constant Euros).[24] Likewise, if growth had not accelerated in the United States (at least from 1995 to 2007, and had remained at the 1980–1995 rate, U.S. GDP would be 5 percent smaller today.[25]

Boosting productivity is critical to the EU's future economic health, in part because the EU's labor force participation rate is lower than that of the United States. A greater share of Europeans retire before the age of 65 than in the United States: 62.5 percent of American workers ages 55–64 are employed, compared with only 57 percent of European workers.[26] Moreover, a greater share of the EU population is above age 65.[27] In 2017, 19.4 percent of the population of the EU-27 nations was 65 years and older, compared with 15.6 percent in the United States.[28] By 2050 that gap is expected to grow even larger, to 28.7 percent in the EU and 20.2 percent in the United States. With so many Europeans consuming and not producing, the only way for Europe to enjoy rising per capita incomes (absent raising the retirement age) is to increase the rate of productivity growth.

To see how important productivity is to future prosperity, consider that if EU labor productivity were to grow over the next 25 years at its 1980–1995 average of 2.3 percent per year, real output per capita would increase by 73 percent, which is significantly more than enough to pay for the increased retiree population, while at the same time ensuring after-tax worker incomes continue to rise. However, if Europe's current low productivity growth rate persists, real output per capita would grow just 15 percent—not enough to even cover increased retirement costs from the greater share of retirees.[29]

BOX 1: PRODUCTIVITY, INNOVATION, AND COMPETITIVENESS

The terms productivity, innovation, and competitiveness are often confused in both the media and popular consciousness, but there are important distinctions between them.[30]

Productivity—the most fundamental of the three concepts—is the ratio of output to input, where output is valued using the amount of goods or services and input is typically an hour of labor, a single worker, or a combination of workers and physical capital. Using hours of work or the number of workers as the denominator yields labor productivity (the measure used in this report unless otherwise specified), while using the combination of workers, physical capital, and other inputs as the denominator yields total factor productivity (TFP). TFP is also called multifactor productivity (MFP) when using only workers and physical capital.

Productivity is the main determinant of national income per person, because over the long term, a nation can consume the amount it produces. Nations can increase their productivity in two ways. When most industries, even low productivity ones, increase productivity, this is the "growth effect." The "shift effect" occurs when an economy shifts resources from less-productive industries (e.g., call centers) to more productive ones (e.g., software). The lion's share of productivity growth for almost all nations, especially larger ones, however, comes not from shifting the sectoral mix to higher-productivity industries, but from the growth effect: all or most industries boosting their productivity.[31]

For individual industries, productivity gains can occur in three ways: through all or most firms increasing their productivity by innovating or adopting new technologies; less productive firms dying and being replaced by new, more productive firms; or by more productive firms gaining market share from less productive ones. In the past 20 years, firm-level research has shown there are large, persistent productivity gaps between firms in the same industry, which means there are large productivity gains to be made from moving toward best-practice production techniques, such as effectively using ICT.[32] In addition, ICT can boost productivity by making older, less productive business models obsolete in favor of newer ones (e.g., online book selling replacing brick-and -mortar bookstores).

Innovation means developing a new or significantly improved product (a physical good or service), production process, marketing method, or organizational method in business practices, workplace organization, or external relations.[33]

Competitiveness is a more complicated concept: It relates to the economic health of a region's or nation's traded sectors whose output can be purchased by consumers outside the region or nation. But how do we define health? The true definition of competitiveness is the ability of a region to export more in value-added terms than it imports. This calculation includes accounting for "terms of trade" to reflect all government "discounts," including an artificially low currency, suppressed wages in export sectors, artificially low taxes on traded-sector firms, and direct subsidies to exports. It also controls for both tariff and nontariff barriers to imports.[34]

Under this definition, a nation may run a large trade surplus (a component of competitiveness). But if it does so by providing large discounts to its exporters or by restricting imports, it would not be truly competitive—for such policies would reduce its terms of trade by requiring its residents to give up some of their income to foreign consumers, pay higher prices for foreign goods and services, or both.

Policymakers, not just in Europe but around the world, tend to prioritize the three factors in order of competitiveness, innovation, and then productivity. But for most nations and regions, especially large ones like Europe, productivity is the most important driver of economic well-being. The majority of jobs in Europe are in nontraded sectors where productivity gains go directly to European workers and consumers. Moreover, productivity gains in traded sectors help both EU consumers and producers.

With so many Europeans consuming and not producing, the only way for Europe to enjoy rising per capita incomes (absent raising the retirement age) is to raise the rate of productivity growth.

ICT AND PRODUCTIVITY GROWTH

Productivity increases stem from a variety of factors, but the principal one is use of more and better "tools" by producers—in other words, the use of more and better machinery, equipment, and software. And in today's knowledge-based economy, the tools that are most ubiquitous and effective in raising productivity are ICT-based. These digital tools are more than simply the Internet, although that itself drives growth.[35] They include hardware, software, and telecommunications networks, and tools that incorporate these components in them, such as IOT devices, AI, and robotics.

These tools can be used in the internal operations of organizations (business, government, and nonprofit); transactions between organizations; and transactions between individuals and organizations. Indeed, ICT has enabled the creation of a host of tools to produce, manipulate, organize, transmit, store, and act on information in digital form in new ways and through new organizational forms. And its impact is pervasive as it is being used in virtually every sector, from farming to manufacturing to services to government.

ICT is a key driver of productivity because it is what economists call a general-purpose technology (GPT). GPTs have historically appeared at a rate of once every half century, and they represent systems of fundamentally new technologies that change virtually everything, including what economies produce; how they produce it; how production is organized and managed; the location of productive activity; the skills required for productive activity; the infrastructure needed to enable and support production; and the laws and regulations needed to maintain or even allow it.[36] GPTs share a variety of characteristics. They typically start in relatively crude form for a single purpose or very few purposes and increase in sophistication as they diffuse throughout the economy. They engender extensive spillovers in the forms of externalities and technological complementarities, and their evolution and diffusion span decades.[37] Moreover, GPTs undergo rapid price declines and performance improvements; become pervasive and an integral part of most industries, products, and functions; and enable downstream innovations in products, processes, business models, and business organization.

ICT led to the U.S. productivity rebound in the 1990s. In a conclusive review of over 50 scholarly studies on ICT and productivity published between 1987 and 2002, Dedrick, Gurbaxani, and Kraemer found that "the productivity paradox as first formulated has been effectively refuted. At both the firm and the country level, greater investment in ICT is associated with greater productivity growth."[38] In fact, nearly all scholarly studies from the mid-1990s have found positive and significant effects of ICT on productivity.[39] The beneficial effects of ICT on productivity have been found across different levels and sectors of economies, from firms to industries to entire economies, and in both goods- and services-producing industries.[40] Buiatti and Sáenz concluded that in Europe, ICT diffusion is "positively related with productivity levels in wholesale and retail trade and transport, suggesting that these sectors enjoy productivity gains in countries with widespread ICT diffusion. The degree of Internet usage and installation of secure servers is also positively associated with productivity in business services."[41] Research by Dimelis and Papaioannou provides "evidence in favor of an impact of ICT well above its income share… Overall, our results indicate that ICT can affect growth not only through higher capital deepening and higher labor productivity growth."[42] Likewise, Diermeier and Goecke wrote, "As soon as enterprises start applying productivity enhancing technologies, an impact on TFP [total factor productivity] can be found; even at the macro-level.[43] Firm-level studies have also shown that firms with high levels of ICT are more likely to grow (in terms of employment) and less likely to go out of business.[44]

The United States was the first country to show large productivity gains from ICT. Between 1995 and 2002, ICT was responsible for two-thirds of total factor productivity growth in the United States, and virtually all of the growth in labor productivity.[45] While productivity increases slowed in the mid-2000s, ICT continued to be an important source of growth: IT-using and IT-producing industries were the only source of value-added growth between 2005 and 2010, as low-IT-using industries lost productivity over that time.[46] Approximately one-third of U.S. growth over that period is attributable to the adoption of ICT by organizations.[47]

Why has the use of ICT been a key driver of growth? A principal reason is it has a greater impact on productivity and growth than non-ICT capital. Studies in the early 2000s found that investment in ICT capital increased productivity by three to eight times more than investment in non-ICT capital.[48] Likewise, Wilson found that of all types of capital, only computers, communications equipment, and software are positively associated with multifactor productivity.[49] Hitt and Tambe found that the spillovers from IT nearly double the impact of IT investments.[50] Rincon, Vecchi, and Venturini confirmed the GPT nature of ICTs through an exhaustive industry-level study of both productivity benefits and spillovers.[51] These studies have been corroborated with research on the benefits of ICT in a richer variety of contexts, including developing countries and public-sector organizations.[52]

However, while ICT drove significant productivity gains in the 1990s and through the mid-2000s, since then, productivity growth has slowed, both in Europe and the United States. There is an enormous debate in the field of economics about the causes of this overall decline. Some blame mismeasurement.[53] Some argue that it takes time for companies to learn to use the technologies.[54] Others claim there are no more technological opportunities.[55]

A more likely explanation is we are between technology waves. The conventional economics view of innovation, to the extent economists have one, is that innovation is linear in nature, something that just happens regularly. But in fact, technological innovation appears to follow a pattern of repeating "S curves," with waves of technology emerging and then stagnating before the next new wave. This is what Joseph Schumpeter argued when he wrote, "Each of the long waves in economic activity consists of an 'industrial revolution' and the absorption of its effects."[56] He went on to state:

One can make a reasonably strong argument that we are closer to the end than the middle of the current digital technology S curve.

> These revolutions periodically reshape the existing structure of industry by introducing new methods of production—the mechanized factory, the electrified factory, chemical synthesis, and the like; new commodities, such as railroad service, motorcars, electrical appliances; new forms of organization–the merger movement; new sources of supply—La Plata wool, American cotton, Katanga copper; new trade routes and markets to sell in and so on. This process of industrial change provides the ground swell that gives the general tone to business; while these things are being initiated we have brisk expenditure and predominating prosperity—interrupted, no doubt, by the negative phases of the shorter [business] cycles that are superimposed on that groundswell.[57]

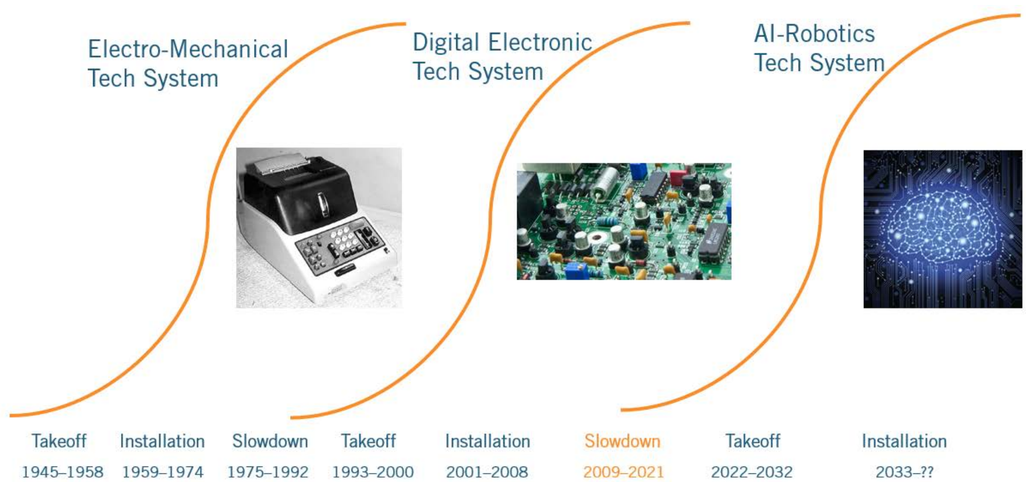
The key to Schumpeter's analysis was the insight that innovation is not a regular process bringing steady incremental improvements, but rather a discontinuous process that leads to waves of technological innovations. He notes that "these revolutions are not strictly incessant; they occurred in discrete rushes which are separated from each other by spans of comparative quiet. The process as a whole works incessantly, however, in the sense that there is always either revolution or absorption of the results of revolution, both together forming what are known as business cycles."[58]

So, perhaps the most important question in understanding where we are vis-à-vis productivity is where we are on the technology S curve. If we are in the middle of the current ICT-powered curve, then it suggests at least a decade or two of robust growth before the expected slow-growth intervening period preceding the next big technology wave. If we are at the end, it suggests we are in for slower growth.

One can make a reasonably strong argument that we are closer to the end than the middle of the current digital technology S curve (figure 6). This is true for two reasons. First, with regard to the existing ICT innovations, most are less transformative than those of a decade or two ago. Take broadband telecommunications. Moving from a 56 K dial-up modem to a 2 MB broadband connection in the late 1990s and early 2000s was a huge improvement. Not only did speed increase by a factor of 36—and users were provided an always-on model—the new speeds supported a wholly different set of applications than the old ones, including voice and video. Going from 2 MB to 12 MB after that was less valuable, not only because it represented only a six fold increase in speed, but because it did not really enable a whole suite of new applications and uses, it just largely made existing ones work better.[151] Likewise, going in the next decade from 12 MB to 100 MB or even a gigabit per second is likely to do little to enable innovation, unless somehow new applications that require super-fast speeds are developed. So far, they are not here. We can see similar dynamics in operating systems. The shift from DOS to Windows was major, but the regular improvement in operating systems from Microsoft, while helpful, is not transformational. Similarly, moving from the x86 Intel microprocessor series to the Pentium in the mid-1990s was a huge step. Going from Pentium to today's core processors, though certainly a major increase in performance, is less important—at least to the average PC user. Today, many people talk about the emergence of cloud computing as a similar revolution to the Internet. But as useful as the cloud is in reducing costs and improving functionality, it is a stepwise increase in Internet functionality, compared with the emergence in 1995 of the Netscape browser and client-server computing. This ICT maturity, more than any other factor, likely explains the slowdown over the last decade in both capital investment and productivity in advanced economies.[59]

Many of the "gee-whiz" applications tech enthusiasts point to as proof of productivity drivers—AI, autonomous vehicles, drones, and flexible robots—are still quite nascent.

Figure 6: General purpose technologies progress along S curves



Second, many of the "gee-whiz" applications tech enthusiasts point to as proof of productivity drivers—AI, autonomous vehicles, drones, and flexible robots—are still quite nascent. Some, like AI, although improving and able to be used in a number of areas such as medical diagnosis, still have a way to go before they affect a not insignificant share of work processes. Others, like autonomous vehicles, are not good enough for full autonomy and are likely to have a price point, at least for a while, that will serve as a high barrier to widespread adoption.

If this periodization is correct, it suggests the current period of incremental growth and relative stagnation will eventually be replaced with a new, sixth technology wave grounded in new technologies that will be so powerful organizations and people will be compelled to buy them en masse. Several technologies look like candidates to comprise the next innovation wave: IOT, advanced robotics, blockchain, new materials, autonomous devices, and AI. Perhaps the most important is AI, which has many functions, including but not limited to learning, understanding, reasoning, and interaction.[60] There are two very distinct types of AI: narrow and strong. Narrow AI describes computer systems that are adept at performing specific tasks, such as Apple's virtual assistant, Siri, which interprets voice commands.[61] "Strong AI," also referred to as artificial general intelligence (AGI), is a hypothetical type of AI that can meet or exceed human-level intelligence using its problem-solving ability.[62] Many of the fears about AI, such as that it will eliminate most jobs, stem from the notion that AGI is feasible and imminent.[63] However, at least for the foreseeable future, computer systems that can fully mimic the human brain are only going to be found in Hollywood scripts—not in Silicon Valley labs.

While these technologies are already in the marketplace, they generally are too expensive and insufficiently powerful to drive economy-wide productivity. For example, despite the excitement over "Industry 4.0" IOT technologies, most manufacturers appear to be in the very early stages of adopting these systems. Likewise, while there is considerable excitement about machine learning software systems, their current capabilities remain relatively limited, notwithstanding some promising early applications. Fully autonomous cars at a price point most consumers can afford are likely at least 15 years away.[64] And fully dexterous robotic hands are not likely to hit the market before 2030 or even 2040.[65] As Rodney Brooks wrote, "Having ideas is easy. Turning them into reality is hard. Turning them into being deployed at scale is even harder."[66]

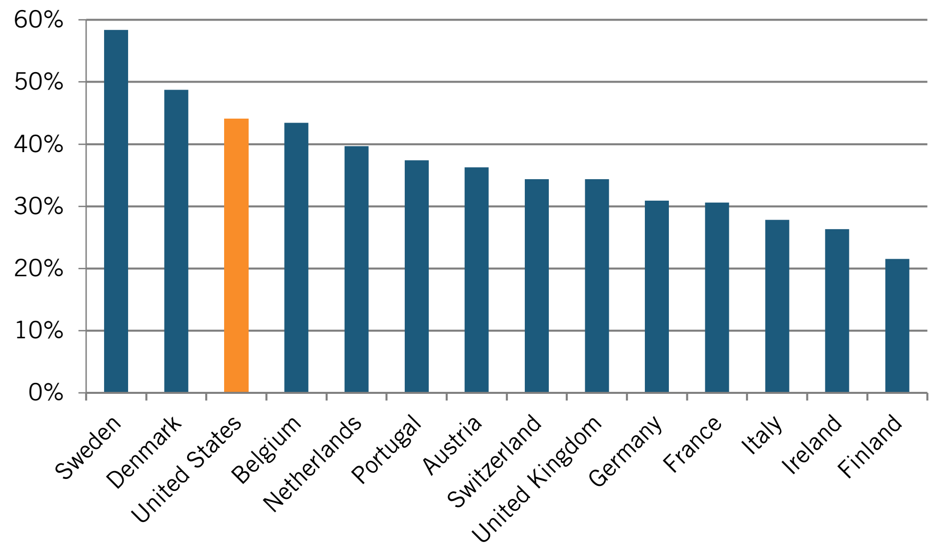
However, if this next wave of innovation follows prior technological trajectories, the technologies will likely experience rapid price declines and significant performance improvements over the next decade. As this occurs, they will be ready for, in the words of innovation scholar Carlota Perez, widespread "installation," wherein they provide enough of a compelling value proposition for a wide range of organizations to scrap existing technologies that have not been fully depreciated and replace them with more-productive new technology systems.[67]

THE IMPACT OF ICT ON EUROPEAN PRODUCTIVITY

One reason the EU has had lower productivity growth than the United States since the emergence of the Internet age is it has had lower productivity gains from ICT.

Van Welsum, Overmeer, and van Ark found that ICT contributed 1.3 percentage points to the average annual growth rates of labor productivity in the United States between 1995 and 2007, but only 0.7 percentage points in the EU-15 (64 percent and 57 percent of total labor productivity growth, respectively).[68] OECD data shows that from 1985 to 2016, ICT capital contributed 0.44 percentage points to the average annual GDP growth rate in the United States, and 0.49 in Denmark and 0.58 in Sweden—but only 0.34 percentage points in the United Kingdom, 0.31 in France and Germany, and 0.28 in Italy (figure 7).

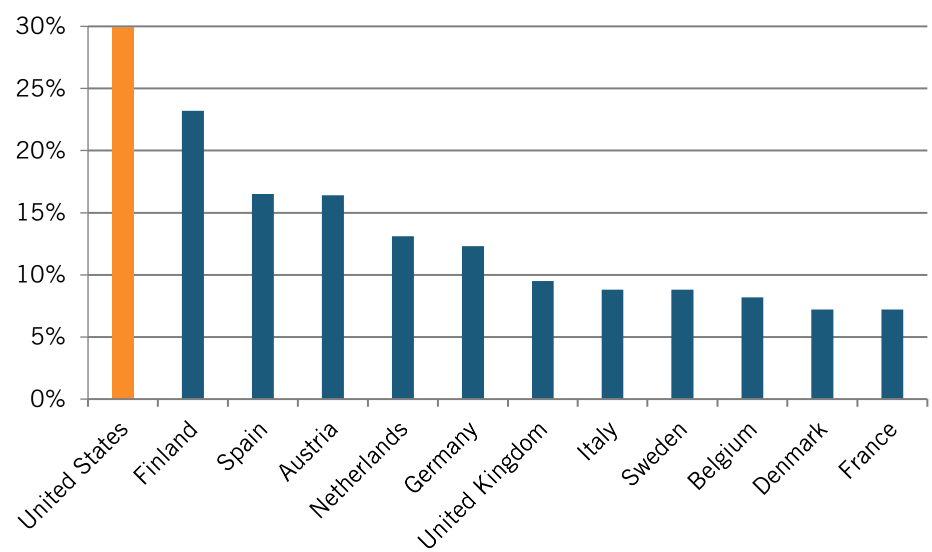
Figure 7: ICT contribution to average annual GDP growth rate, 1985–2016[69]



ICT investment goes hand in hand with firm productivity growth, and thus European productivity growth would have been even slower without investment in ICT.

The United States also obtained a larger share of productivity growth from ICT capital than did other European nations. Between 2013 and 2015, almost 30 percent of U.S. productivity growth was from ICT capital, compared with generally between 7 and 23 percent in select EU nations (figure 8).

Figure 8: Share of productivity growth from ICT capital services[70]



Even though the impacts of ICT EU-wide have not been as great as in the United States, we can still clearly see ICT benefits in Europe at the firm and industry levels. In the United Kingdom, several industry-level studies have found that ICT plays an important role in productivity growth. Corry et al. found that the contribution from the "knowledge economy," which includes labor composition, ICT capital, and TFP, increased in the United Kingdom from 2 to 2.3 percentage points of overall growth from 1997 to 2007.[71] Goodridge, Haskel, and Wallis found sectors that contributed most to value-added growth in the United Kingdom between 2000 and 2009 invested most heavily in ICT capital.[72] In Finland, Mairesse, Rouvinen, and Ylä-Anttila discovered that ICT adoption contributed significantly to non-ICT-sector productivity growth between 1994 and 2007.[73]

On a firm level, the benefits of Internet and computer use for productivity are also well established. A large number of studies in the late-1990s and early-2000s confirmed at a micro level that ICT has a positive effect on firm productivity in both the United States and Europe.[74] Varian et al., for example, found that firms in the United Kingdom, France, and Germany increased revenues 8.6 percent and decreased costs 2.6 percent through the use of Internet business systems; Johnston, Wade, and McClean likewise found that e-business uptake increased revenues in small- and medium-sized enterprises by 9 percent.[75] In a large survey of German firms, Bertschek, Fryges, and Kaiser found that firms that engaged in business-to-business e-commerce significantly increased both multifactor and labor productivity.[76]

Studies have continued to show the benefits of ICT after the initial years of the Internet boom as well. In a study of 1,955 European firms, Nurmilaakso found that Internet access and standardized data exchange with trading partners contributed to significant increases in labor productivity.[77] Similarly, Koellinger found that firms in the EU that implemented eight e-business practices were more than twice as likely to report that they had both increased productivity and expanded employment over the past year.[78] Castiglione measured the impact of ICT investments in Italian manufacturing firms and found they had a positive and significant effect on firms' efficiency, corroborating earlier work by Milana and Zeli.[79] Iammarino and Jona-Lasinio found that Italian regions with significant ICT production have greater labor productivity and are the primary drivers of national growth.[80] Also in Italian firms, Hall, Lotti, and Mairesse found that ICT investment is strongly associated with productivity.[81] Ruiz-Mercader, Meroño-Cerdan, and Sabater-Sánchez found that e-business solutions increased organizational performance by expanding industry learning and organizational efficiency.[82] In France, Chevalier, Lecat, and Oulton found that since 1992, firms near the technological frontier have increased productivity relative to other firms, attributing the speedup to ICT adoption and globalization.[83] In another study, 29 percent of Danish small manufacturers indicated their competitive position was strengthened a great deal by doing business online.[84] Firm-level data also makes it possible to look at these effects. A study by Bruegel looked at the top 25 percent of firms in the EU in terms of productivity distribution.[85] For the firms that adopted an ICT instrument, the log of their labor productivity was 4.70, compared with 4.56 for firms that did not adopt any ICT instruments. For the firms that adopted two or three ICT instruments, their median log productivity was 5.03. These studies confirm that ICT investment goes hand in hand with firm productivity growth, and thus European productivity growth would have been even slower without investment in ICT.

Why Has Europe Not Gained as Much From ICT?

If ICT has such large productivity benefits at the firm-, industry-, and economy-wide levels, why has Europe failed to gain from ICT the way the United States has? There are a number of reasons.

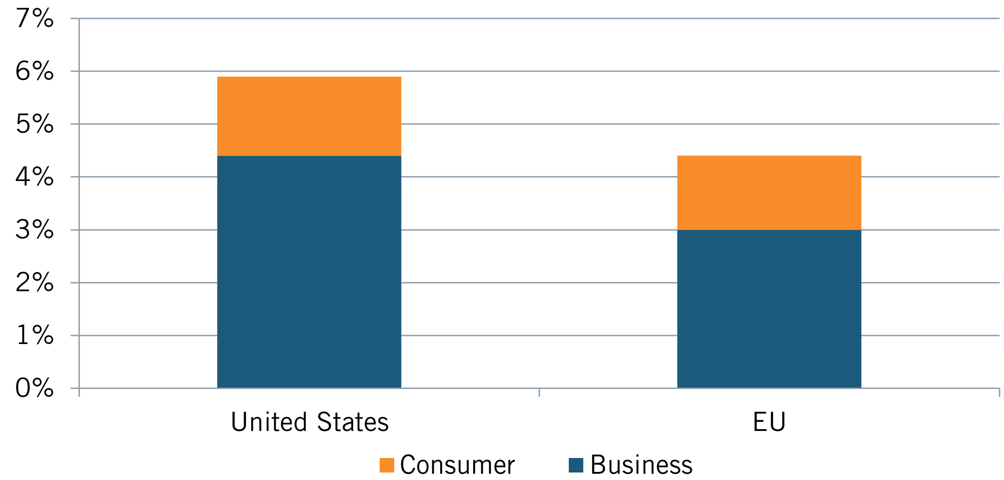
Less ICT Investment

On average, firms in Europe do not invest as much in ICT as firms in the United States. Higher levels of ICT investment drive higher productivity growth.

On average, firms in Europe do not invest as much in ICT as firms in the United States. Higher levels of ICT investment drive higher productivity growth. In a recent survey of both micro and macro literature, Cardona et al. noted that firm-level analyses provide "solid evidence that over the last two decades an increase of ICT investment by 10% translated into higher output growth of 0.5–0.6%" regardless of the country studied.[86] Strauss and Samkharadze argue, "US productivity has outgrown the EU-15 mainly because of stronger ICT capital deepening and faster progress in productive efficiency."[87] As Van Ark wrote, "The weak pace in TFP (total factor productivity) growth characterizes the slow diffusion of technology and innovation largely related to the weak growth of ICT capital and other important investments in productivity-related capital."[88] Likewise, Ketteni, Mamuneas, and Pashardes wrote, "Thus, more ICT capital (more investment in ICT and in ICT adoption) in EU countries can reap significant benefits in terms of productivity and, consequently, competitiveness and GDP growth."[89] Another study by Chen that looked at the ratio of ICT capital to labor in multiple industries in all EU nations compared with the United States from 1995 to 2007 found that the average ICT capital intensity in U.S. firms was 1.5 times greater than EU firms.[90] And in only 22 percent of the 1,430 cases (e.g., a particular year, industry, and nation) was EU ICT capital intensity greater than that of the United States.

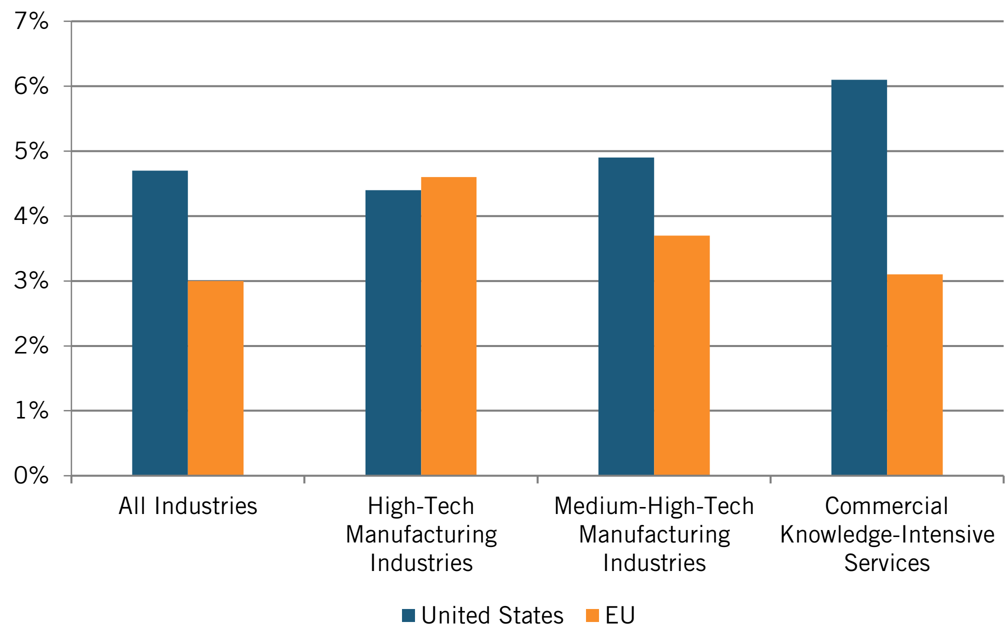
In a wide array of indicators, it is clear U.S. firms invest more in ICT. In 2010, for example, both businesses and consumers in the United States spent more as a share of GDP (figure 9).[91]

Figure 9: Business and consumer spending on ICT as a share of 2010 GDP[92]



In 2016, ICT spending by business as a share of value added was 56 percent higher in the United States than in the EU, and 97 percent higher in the services sector (figure 10).

Figure 10: ICT business spending as a share of industry value added, 2016[93]



Moreover, in the United States, a larger share of business capital investments is in ICT—and since 2000, that share has fallen more in the EU (figure 11). In 2000, 31 percent of total nonresidential investments were in ICT in the EU-15, compared with 32 percent in the United States. By 2016, the EU-15 share had fallen to 23 percent, while the U.S. share fell to 27 percent (figure 12).

Figure 11: Gross fixed-capital formation (investments) by type as a percentage of GDP[94]

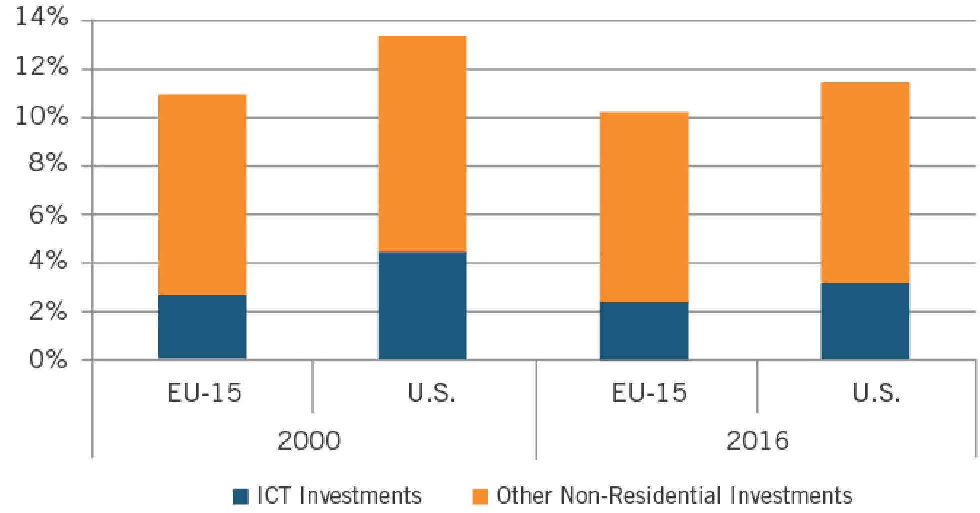
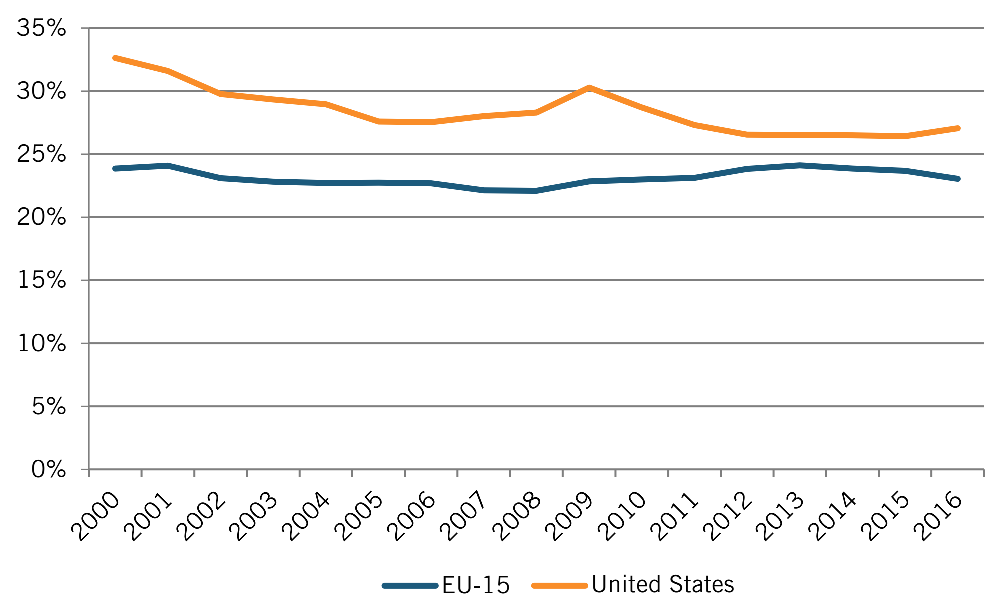


Figure 12: Share of nonresidential investments that are in ICT[95]



Moreover, U.S. ICT investment is significantly higher as a percentage of overall investment than in any European nation except France and the Netherlands (figure 13).[96] And it is higher as a share of GDP than Austria, France, Sweden, and the Netherlands (figure 14).

Figure 13: ICT investment as a share of total investment, 2016 (or latest data available)[97]

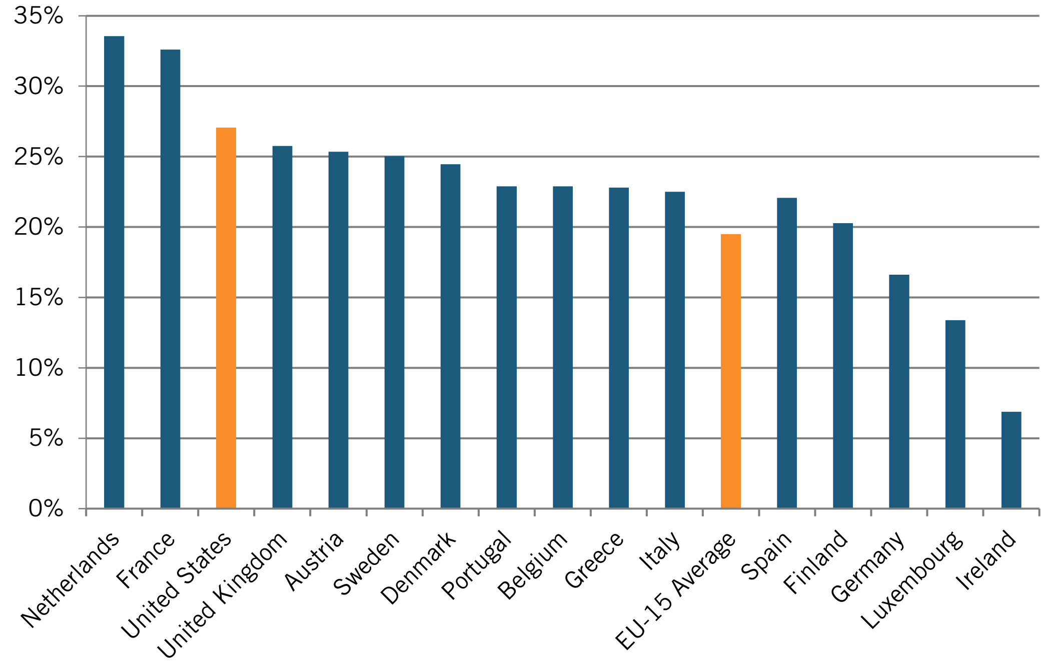
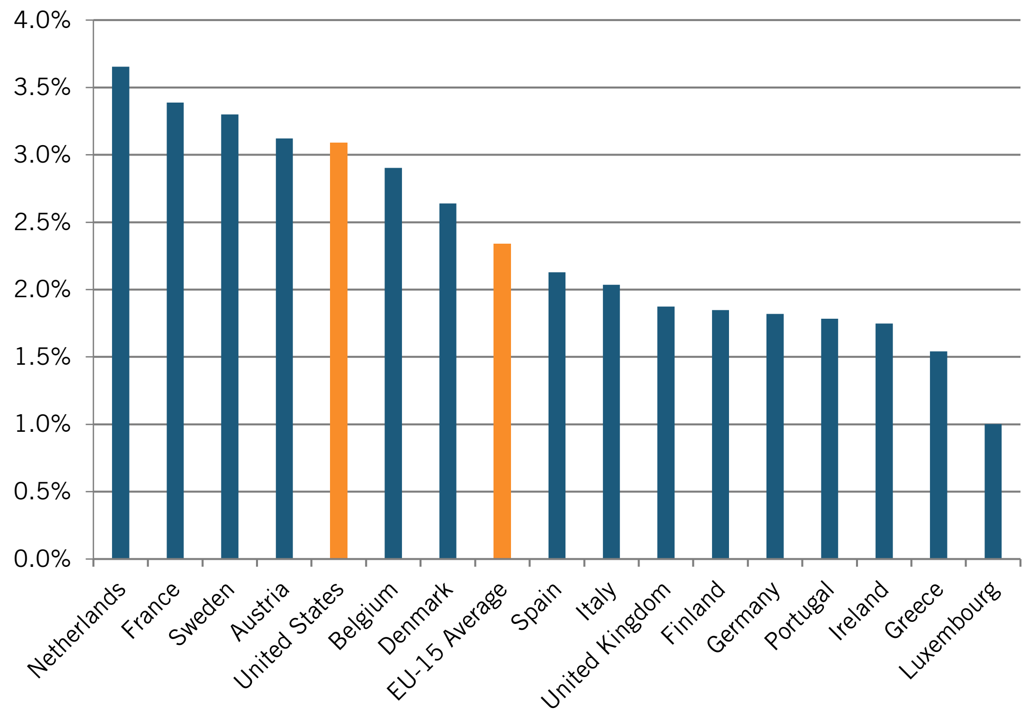


Figure 14: ICT investment as a share of GDP, 2016[98]

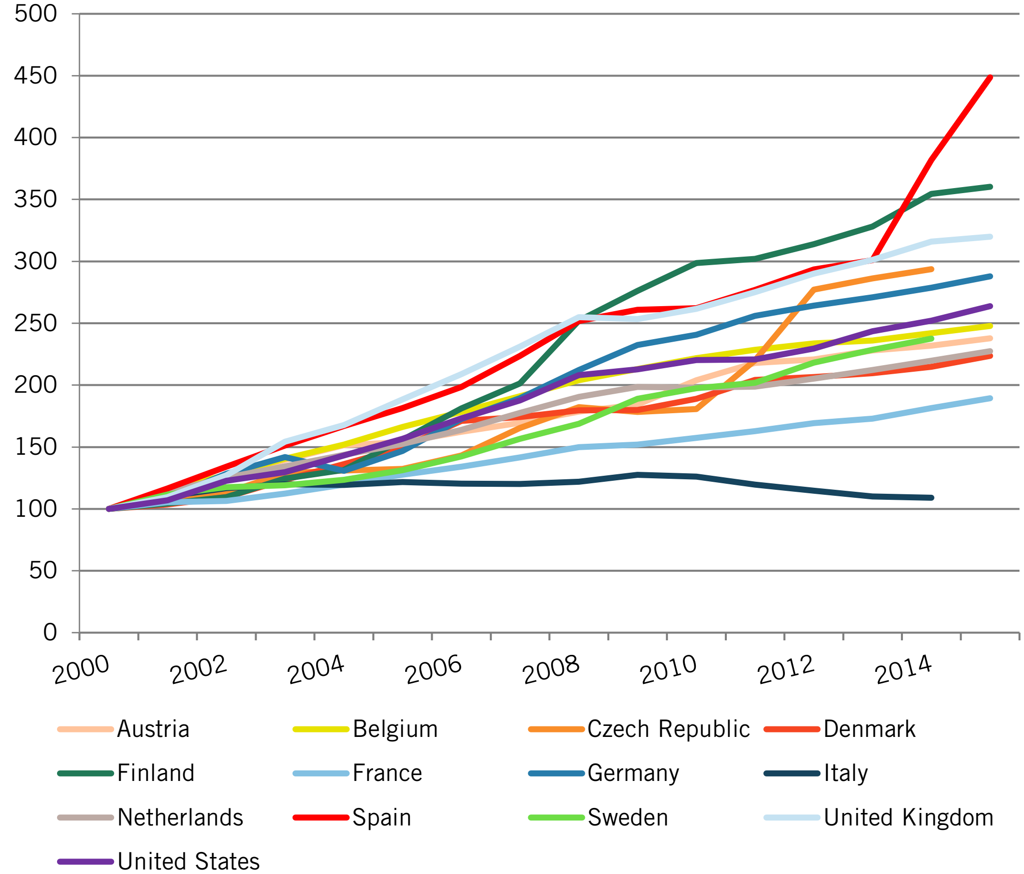


Some EU nations have grown their ICT capital stock faster than the United States, when using 2000 as a starting point. From 2000 to 2015, ICT capital stock—the total accumulated ICT investment—grew more rapidly in Spain, Finland, the United Kingdom, Czech Republic, and Germany.[99] But it grew more slowly than the United States in Belgium, Sweden, Austria, the Netherlands, Denmark, France, and Italy (figure 15).

Table 3: ICT specialists as a share of total employment[100]

Country	ICT Specialists as Share of Total Workforce 2016
Finland	6.24%
Sweden	5.62%
Estonia	5.12%
United Kingdom	4.95%
The Netherlands	4.50%
Denmark	4.41%
Ireland	4.26%
Luxembourg	4.12%
United States	**4.06%**
Austria	3.79%
Belgium	3.76%
EU-15 Average	**3.69%**
Germany	3.58%
Czech Republic	3.44%
Hungary	3.40%
Slovenia	3.18%
France	3.09%
Spain	3.01%
Italy	2.76%
Portugal	2.76%
Slovak Republic	2.43%
Poland	2.40%
Latvia	2.00%
Lithuania	1.95%
Greece	1.81%

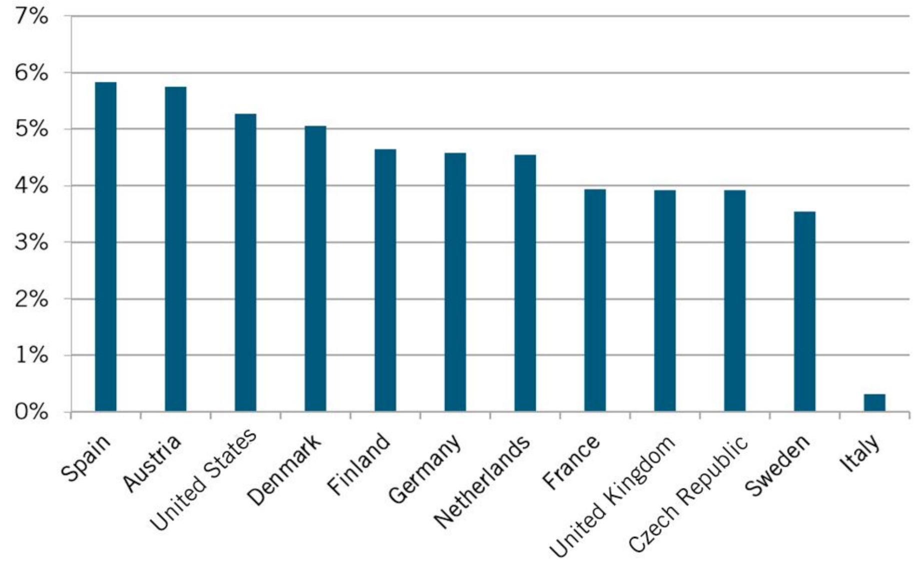
Figure 15: ICT capital investment (each country's investment indexed at 100 in 2000)[101]



One indicator of this weaker EU investment in ICT is the workforce share of ICT. While some, mostly smaller, EU economies employed a larger share of ICT specialists (e.g., Finland, Sweden, Estonia, United Kingdom, the Netherlands, Denmark, Ireland, and Luxembourg), the U.S. rates were higher than all other EU economies, including France, Germany, Italy, and Spain—and higher than the EU-15 average (table 3).

The relative share of type of ICT investment differs by nation as well. A larger share of ICT investment in the United States is in software than in most EU nations. From 2000 to 2015, software's capital stock grew faster in the United States (5.26 percent annual growth) than in any major European nation except Spain (5.82 percent) and Austria (5.74 percent) (figure 16).[102] Moreover, in 2015, software's capital stock as a share of GDP was higher in the United States than in other EU nations except France, Sweden, Austria, Denmark, and the United Kingdom (table 4). And in 2013, fewer than 5 percent of EU-27 firms made investments in software development greater than 5 percent of revenues, compared with 9 percent of U.S. firms.[103]

Figure 16: Real annual growth in software capital stock, 2000–2015[104]



Software is now central to innovation in a wide array of ICT areas (e.g., cloud, telecommunications [software-defined networks], AI and data innovation, and new processes for developing enterprise software [Dev-ops]).

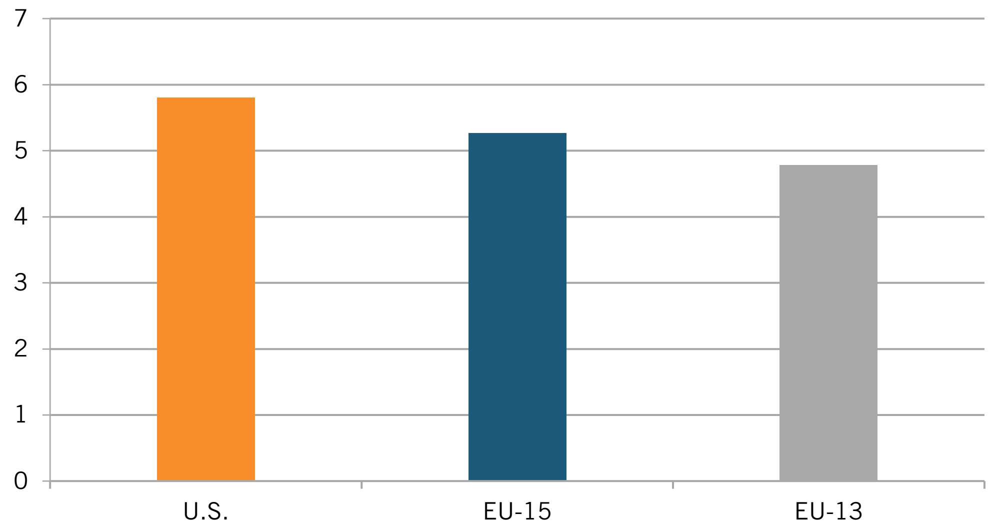
This is important because it appears software has become the most important component of ICT capital (software, IT equipment, and communications equipment). As Robert Cohen wrote in an analysis of the "softwarization" of the U.S. economy, "Software innovations have become central to business operations." As a result, he wrote, "Software is a 21st Century GPT (general purpose technology)."[105] This is why Netscape founder and venture capitalist Marc Andreesen famously said that "software is eating the world." We see that software is now central to innovation in a wide array of ICT areas (e.g., cloud, telecommunications [software defined networks], AI and data innovation, and new processes for developing enterprise software [Dev-ops]).

Table 4: ICT capital stock by asset as a share of GDP, 2015[106]

Country	IT Hardware	Tele-communications	IT Software	ICT Total
Austria	1.2%	6.8%	5.7%	13.7%
Spain	1.8%	6.4%	4.8%	12.9%
Sweden	1.5%	4.5%	6.6%	12.6%
United States	1.4%	4.3%	4.8%	10.5%
Denmark	3.8%	1.2%	5.3%	10.3%
The Netherlands	2.1%	0.4%	7.1%	9.6%
France	0.7%	1.3%	7.2%	9.2%
Germany	3.4%	2.7%	2.6%	8.7%
United Kingdom	1.7%	0.5%	5.1%	7.3%
Italy	1.1%	1.6%	4.2%	6.9%
Finland	1.1%	1.9%	3.1%	6.2%

The difference in ICT intensity shows up in survey data on ICT use as well. The 2016 World Economic Forum's Networked Readiness Index survey shows that the EU-15 and EU-13 trail behind the United States in ICT adoption, business-to-business Internet use, business-to-consumer Internet use, and staff ICT training (figure 17).[107]

Figure 17: Average of 4 indicators of ICT use (1–7, where is 7 highest use)[108]



Larger Regional and Sectoral Divergence

One challenge for Europe taking advantage of ICT is the very large divergence between leaders and laggards in ICT adoption. Some EU nations, such as the Nordic nations, are generally on par, or even ahead of the United States. But many other EU nations, including the EU-10 and southern EU nations, lag significantly behind EU leaders. For example, use of Customer Relationship Management Software (CRM) and e-commerce differs by more than a factor of six between the nation with the highest rate of adoption as share of enterprises (Ireland) and the lowest (Greece), and a factor of five for ICT specialists as a share of total employment.[109] The difference is even higher (eight times) for cloud computing between the leading nation (Finland) and the laggard (Bulgaria).[110] For example, when looking at the adoption rate of ecommerce orders by enterprises, this varies from 33 percent in Norway to just 8 percent in Romania.[111] In 2016, more than 40 percent of enterprises in Finland, Sweden, and Demark used cloud computing, compared with fewer than 10 percent in Greece, Latvia, Poland, Romania, and Bulgaria.[112]

There also appears to be even less adoption of ICT between industries in Europe. One measure of this is the standard deviation of measurement of ICT capital services as share of labor in different industries. In Europe, this is higher (0.14) than in the United States (0.09), suggesting adoption has been less even across industries.[113] This may be a reason why a recent National Bureau of Economic Research (NBER) working paper shows the regional dispersion of productivity across firms in the European Union is about twice as large as that in the United States. In other words, the gap between the most productive and least productive firms in any particular industry is higher in Europe than in the United

States.[114] This is also what a recent study comparing the productivity of firms across the 28 EU nations and the United States found: The dispersion in the EU is about twice as large—which is consistent with the view that the EU economy is far from being highly integrated. They estimate that reducing the EU dispersion to the level of the United States would increase EU productivity by more than 30 percent.[115]

Advanced Applications: Cloud Computing, AI, IPv6

ICT constantly evolves, often in discontinuous ways. Relatively new and emerging ICT innovations such as cloud computing, IOT, and AI will likely be particularly important in driving future productivity. As van Ark noted, there has been a decline in ICT equipment spending as a share of GDP in many nations, including the United States, United Kingdom, and Germany.[116] Software has generally remained stable, with some slight increases. However, there has been a significant rise in ICT services, such as data storage and information-processing services (including cloud computing), computer systems design, and other information services (including Internet publishing).

Average 2016 broadband speeds in Central and Eastern Europe were 24.8 Mbps, 30.2 Mbps in Western Europe, and 36.1 Mbps in the United States.

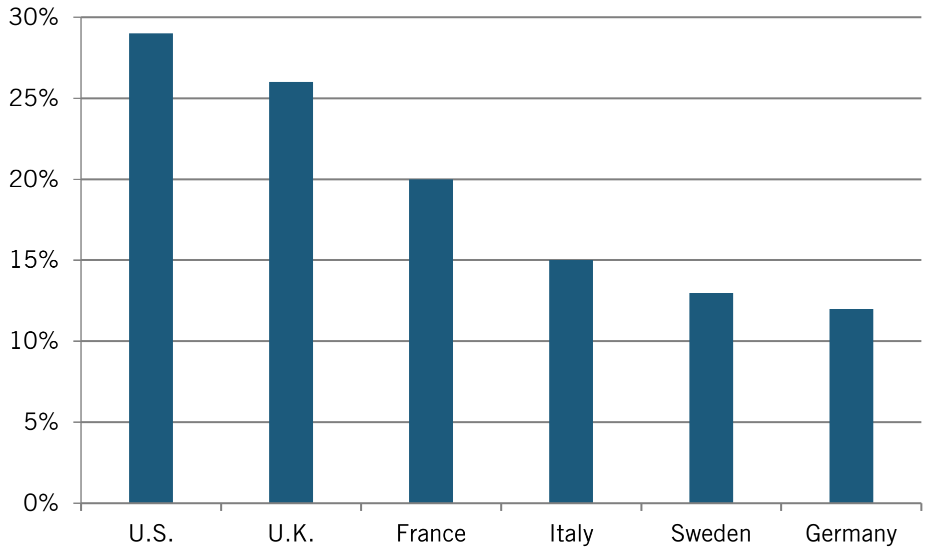
The United States appears to be ahead of Europe in the adoption of advanced IT services. Van Ark wrote that "business spending on digital services (including cloud computing and other information services) relative to output has increased from 1.5 per cent in 2000 to 1.9 per cent in 2014 in the United 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."[117] Likewise, in 2015, 28 percent of companies in North America had undertaken big data initiatives as part of their business compared with just 16 percent in Europe.[118]

It appears the United States also leads Europe in AI adoption. A study by LinkedIn looked at the share of users who have AI-related technologies and skills in their profile. Normalized by the number of LinkedIn users per nation, the United States (0.6 percent) leads major European nations (the Netherlands, 0.5 percent; France, 0.4 percent; and Germany and Italy, 0.3 percent).[119]

A 2017 Teradata survey found that executives in the Americas (Canada and United States) were more likely to adopt AI than their counterparts in Europe. For example, 52 percent of U.S. firms either had a chief AI officer or planned to appoint one within the next 12 months, compared with 39 percent of EU firms.[120] An interesting difference is that while 58 percent of U.S. firms reported they "have trusted vendors and partners that will help us buy, build, and deploy AI technologies and solutions" just 46 percent of EU firms reported the same. That may reflect the United States having more and larger firms providing AI solutions than the EU. At the same time, EU firms were less likely to adopt AI in part because 40 percent of respondents thought the technology "is still nascent and unproven" compared with just 27 percent of U.S. firms.

Similarly, the McKinsey Global Institute found the share of companies that had adopted at least one AI technology (computer vision, natural language processing, machine learning, virtual agents, or robotics) at scale or in their core processes was higher in the United States than the surveyed EU nations. Twenty-nine percent of U.S. companies surveyed had adopted AI at scale, compared with 26 percent of U.K., 20 percent of French, 15 percent of Italian, 13 percent of Swedish, and just 12 percent of German companies (figure 18).[121] Similarly, a study by the Boston Consulting Group found that twice as many U.S. as EU companies had extensively incorporated AI into their processes and offerings (10 percent versus 5 percent).[122] Moreover, in most major industries, U.S. companies had a greater belief than those in the EU that AI would have a significant effect on product offerings—including health care; industrial; energy; technology, media, and telecom; and consumer products—within five years.

Figure 18: Countries with share of companies adopting AI technology at scale or in their core processes[123]



While cloud computing has been in use for at least a decade, cloud services continue to improve and expand in terms of their functionalities, with more organizations adopting the technology. And it is helping to boost productivity. Bryne and Corrado conclude, for the decade to 2014, that for the United States "…about 25 percent of the total 1.4 percentage points estimated contribution of ICT to output per hour growth owes to the diffusion of ICT technology via purchases of cloud and related ICT services."[124]

The EU is behind the United States in cloud adoption. One study estimated, "The United States will be the largest market for public cloud services accounting for more than 60% of worldwide revenues throughout the forecast and total spending of $163 billion in 2021. Western Europe will be the second… largest regions with 2021 spending levels of $52 billion."[125] In other words, By 2021, U.S. spending on cloud computing is projected to be 3.2 times greater than that of the EU, as a share of GDP.

The trend in cloud computing development is toward hyperscale cloud centers; the share of servers in these large centers is expected to grow from 38 percent of 386 data centers in 2018 to 53 percent in 2021.[126] At the end of 2017, North America accounted for 46 percent of the world's hyperscale cloud centers, while Europe accounted for just 19 percent. In other words, the United States had 2.1 times more hyperscale cloud centers per GDP than the EU. Cisco estimates that by 2021, because of growth in Asia, the U.S. share will decline to 35 percent, with Europe's staying at 19 percent.

A reason for the greater IT and cloud adoption in the United States compared with the EU may be broadband speeds being greater in the United States. According to Cisco, average 2016 broadband speeds were 24.8 Mbps in Central and Eastern Europe, 30.2 Mbps in Western Europe, and 36.1 Mbps in the United States.[127] Likewise, average mobile connection speed was 7 Mbps in Central and Eastern Europe and 11.4 Mbps in Western Europe and the United States.

Also, Internet protocol (IP) traffic was significantly higher in the United States. In 2018, it was 42,267 petabytes (PB) per month in the United States, compared with just 24,847 for European nations.[128]

By 2021, U.S. spending on cloud computing is projected to be 3.2 times greater than that of the EU, as a share of GDP.

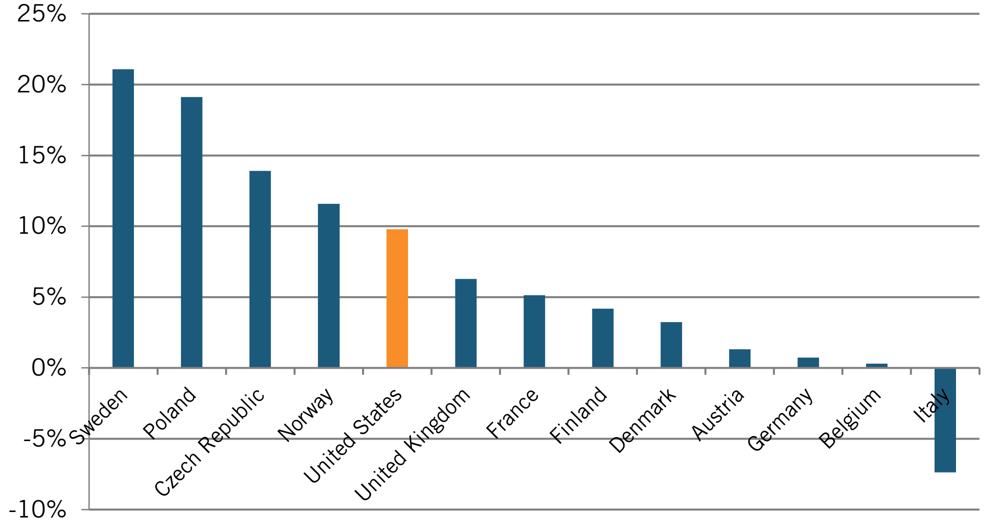
Internet protocol version 6 (IPv6) is an advanced Internet addressing system that enables vastly more IP addresses—something that will be critical for moving to an IOT world.[129] When looking at the share of a nation's web browsers that are IPv6-enabled (as opposed to IPv4) it is clear the United States leads Europe. According to Google data, only Belgium and Germany have a greater share of IPv6 web browsers than the United States,[130] while Akamai data shows that only Belgium leads the United States, with most European nations having IPv6 adoption rates around one-quarter of U.S. rates.[131]

Finally, EU firms appear to be behind firms in other nations when it comes to patenting next-wave technologies. A study by the European Patent Office of the top 25 firms applying for European patents in "industry 4.0" technologies from 2011 to 2016 found that only 16.8 percent were from European corporations, compared with 46 percent of all EU patents in all technology areas in 2016 being issued to Europeans. South Korea was overrepresented, with its share of industry 4.0 patents five times higher than its share of total EU patents.[132] China was 80 percent higher and Japan 50 percent higher. Perhaps surprisingly, the United States was underrepresented, with U.S. firms accounting for 28 percent of EU patents, but only 21 percent of industry 4.0 patents.

Limited Impacts in the Services Sector

Drilling down into the lack of investment, another reason Europe has not experienced the same macroeconomic impacts from ICT as the United States is it has not been able to use ICT to drive service-sector productivity as well as the United States. U.S. service-sector productivity has grown faster than in most major EU countries (figure 19).

Figure 19: Total labor productivity growth in services from 2006–2016[133]



Timmer, O'Mahony, and van Ark estimate that from 1995 to 2007, EU private service-sector productivity grew only one-third as fast as in the United States, primarily due to greater deployment and usage of ICT in the United States in service sectors.[134] Uppenberg found that because services are such a large part of the European (and U.S.) economy, "substantially higher productivity growth in manufacturing would not be sufficient" to remedy the productivity slowdown.[135] Mas argues that it is "the services and not the manufacturing industries that make the difference between the US and the EU. …while in the US TFP improvements in the ICT producer sectors spilled over to the other sectors of the economy (especially the ICT intensive users), in the EU-15 its positive effects were restricted to only the ICT producer sectors."[136] Likewise, Buiatti, Duarte, and Saenz found "the U.S. accelerated from approximately 1% growth in service labor productivity in the 1970–90 period to 1.4% in the 1990–2009 period. At the same time, most European countries experienced a major slowdown in services between the two periods, with the European average growth rate in services falling from 1.6% to 1%."[137] They realized that the total EU labor productivity in 2009 would be significantly larger if the productivity in the service sectors grew as much as in the United States. And they determined this lag was particularly problematic in wholesale and retail trade and business services: "We identify wholesale and retail trade and business services as the types of services that principally caused low service productivity in Europe, and ultimately led to the divergence of European aggregate productivity from U.S. levels since the 90's."[138]

Regulation

Simply knowing that firms in Europe have invested less in ICT than firms in the United States does not tell us why. Several interrelated reasons appear to be at play, one of which is the level of regulation in product markets, labor markets, and land markets.[139] As an OECD report notes, "Excessive regulation of product markets is a barrier to the diffusion of technology and lowers the speed at which labour productivity catches up to the level of the best performing economies."[255] Aghion and colleagues found that liberalizing product markets is key to enhancing productivity growth in developed economies.[256]

Van Reenen et al. found that both product market and labor market regulations "may be significant determinants of cross-country differences in the impact of ICT… [because] "high levels of labor and product market regulation are associated with a lower productivity impact of ICT."[140] They determined that product market regulations act as a productivity drag on ICT, lowering its impact by 16 percent for each dollar invested.[141] The fact that companies in Europe can get less "bang for their buck" from their ICT investment means not only that productivity is lower, but that fewer projects meet investment hurdles—and firms in Europe end up investing less than firms in the United States. This may be why the McKinsey Global Institute estimates that, overall, Europe operates at only 12 percent of its digital potential, compared with 18 percent for the United States.[142]

Likewise, Cette et al. examined product market regulation in six upstream industries (energy, transport, communication, retail distribution, banking services, and professional services). First, they found that the while the undue regulatory burden is lower in the United Kingdom, the Netherlands, and Sweden compared with the United States, it is higher in Germany, Denmark, Spain, Czech Republic, France, Finland, Italy, and Austria.[143] When they estimated the negative effect of regulation on ICT capital investment, only the United Kingdom was lower than the United States, with Italy the highest. This burden, in turn, lowers potential multifactor productivity growth by the most regulated EU economies by between 0.4 and 1 percent a year.[144]

Given that so much of the ICT system is moving to the cloud, requiring a "European Cloud" is likely to have a significant negative impact on European productivity.

Another factor that may play a role in lower productivity and digital adoption is how regulation enables firms to go out of business when they cannot adapt. An OECD study concluded that there is considerable evidence that a cause of lagging productivity in the EU is the increasing gap between leading and lagging firms in terms of productivity, and that in some nations it is easier for those laggard firms to go out of business. It states, "Insolvency regimes and how lengthy and costly it is to dissolve a non-performing business. Nations where it is harder to dissolve zombie firms could have more of them. In 2016, all nations in the EU except Great Britain, Denmark and Germany had higher barriers than the US."[145]

Privacy and Other Consumer Regulations

A product market regulation that appears to have a negative effect on ICT-enabled productivity is privacy regulation. Goldfarb and Tucker showed that EU privacy regulation has decreased the effectiveness of online advertising, reducing the revenue of websites that rely on ad-based business models.[146] This appears to be a reason the EU lags behind the United States in the size and number of Internet companies. Campbell et al. examined the impact of privacy regulations in specific markets, and found that regulation may keep out new firms, some of which may become more productive than incumbents.[147]

Privacy regulations not only limit business models, they also increase the cost of doing business for firms, presumably decreasing their ability to invest. For example, the EU decision on the "right to be forgotten," which requires search engines to delete certain links based on individual requests, raises compliance costs. A report by the European Centre for International Political Economy for the U.S. Chamber of Commerce estimates that the right to be forgotten could decrease EU GDP by 1.5 to 3.9 percent by reducing the productivity and competitiveness of EU ICT companies.[148] Christensen et al. showed that privacy regulations are particularly costly for small and medium-sized enterprises, costing them between €3,000 and €7,200 per year, or 16 to 40 percent of IT budgets.[149] This is why a survey in 2011 found that 63 percent of EU venture capital investors believed that an active opt-in privacy requirement would deter investment in Internet companies dependent on advertising revenue.[150] One study found that in the EU, venture capital (VC) investments into online news, online advertising, and cloud computing increased at a slower pace than in the United States, after the passage of the 2002 EU e-Privacy Directive. VC investment across these three sectors was between 58 to 75 percent lower than it otherwise would have been if the EU and United States had maintained similar trends in investment beyond 2002.[151]

One product market regulation that appears to have a negative effect on ICT-enabled productivity is privacy regulation.

The EU privacy rules may well be why digital advertising expenditures have grown more slowly in the EU than in the United States. From 2012 to 2017, digital ad revenues grew 93.5 percent in the EU, and 140.4 percent in the United States.[152] If EU digital ad revenue had grown at the same rate as in the United States, an additional 11.6 billion euros would be flowing annually to the EU digital ecosystem, including to EU Internet start-ups and publishing companies. To give a sense of the scale, consider that in 2018, mobile app revenues paid for by advertising was an estimated 8 billion euros.[153]

Other examples of costly regulations that limit the effectiveness of IT investment include the law requiring websites to obtain "explicit consent" before using web cookies, and the requirement that companies provide external human involvement as needed in any automatic, IT-enabled process that produces significant or legal effects.[154] The former policy is both overly ambiguous and burdensome, particularly to smaller websites, while the latter is likely to delay progress in the emerging area of big data analytics.[155]

These factors may be why EU firms have been slower to adopt AI software. One survey found that 32 percent of EU executives hesitated to invest in AI because of "complications around policies, regulations and rights," compared with just 22 percent in the United States.[156] This could also be why EU firms focus less on using AI to drive top-line revenue expansion than on reducing costs, because regulatory barriers can make it more difficult to develop innovative and profitable business models around AI. When asked which was the bigger driver for investing in AI—increasing revenues or reducing costs—65 percent of U.S. firms focused on the former, compared with 45 percent of EU firms.[157]

Likewise, according to an industry-funded study, European requirements regarding physical labels on electronic devices, as opposed to electronic labels, have been estimated to cost industry 797 million euros per year.[158] Not only are requirements for physical labels normally not required, they also add to the cost of electronic devices.[159]

Labor Market Regulations

Labor market regulations have a large negative impact on ICT investment and the benefits firms can obtain from it. Van Reenen et al. found that labor market regulations reduce productivity gains from ICT by approximately 45 percent.[160] The authors attribute one-third of this effect to how labor market regulations can slow down the entry and exit of firms: Stricter regulations can protect and preserve less-productive, less-technologically advanced firms.[161] Labor market regulations also reduce the flexibility of managers, preventing them from reorganizing production in more efficient ways.[162] Why buy IT to reorganize production and cut costs when regulations make it difficult to reduce the workforce? Antonelli similarly found that rigid labor markets make firms less likely to adopt new technologies.[163] They also appear to reduce productivity gains through outsourcing and offshoring—as business practices rely heavily on ICTs. Europe was slower to offshore and outsource production in the 2000s, and while it caught up to the United States in total outsourcing spending after the Great Recession, U.S. firms remain far ahead of European firms in terms of outsourcing and offshoring core business functions.[164] Again, such rules reduce the return on investment from ICT purchases, leading firms in Europe to invest less than firms in the United States.

As a result, countries with high labor regulation adopt more technologies in the low-skill sectors and less in the high-skill ones, while countries with lower labor regulation have more technologies within the high-skill sector.[165] O'Mahoney and van Ark argue that labor market policies led to substitution of labor by capital in sectors where labor is protected by regulation and wages are higher. Acemoglu, Koeniger, and Leonardi found that in a comparison between the United States and Germany, labor-capital substitution has been larger than what can be explained by changes in factor prices alone.[166]

As a result, countries with high labor regulation adopt more technologies in the low-skill sectors, and less in the high-skill, while countries with lower labor regulation have more technologies in the high-skill sector.[167] A study of European productivity growth from ICT found that firms that combine ICT with intangible capital—especially R&D and organizational innovation—get a larger productivity benefit than firms that only use ICT.[168]

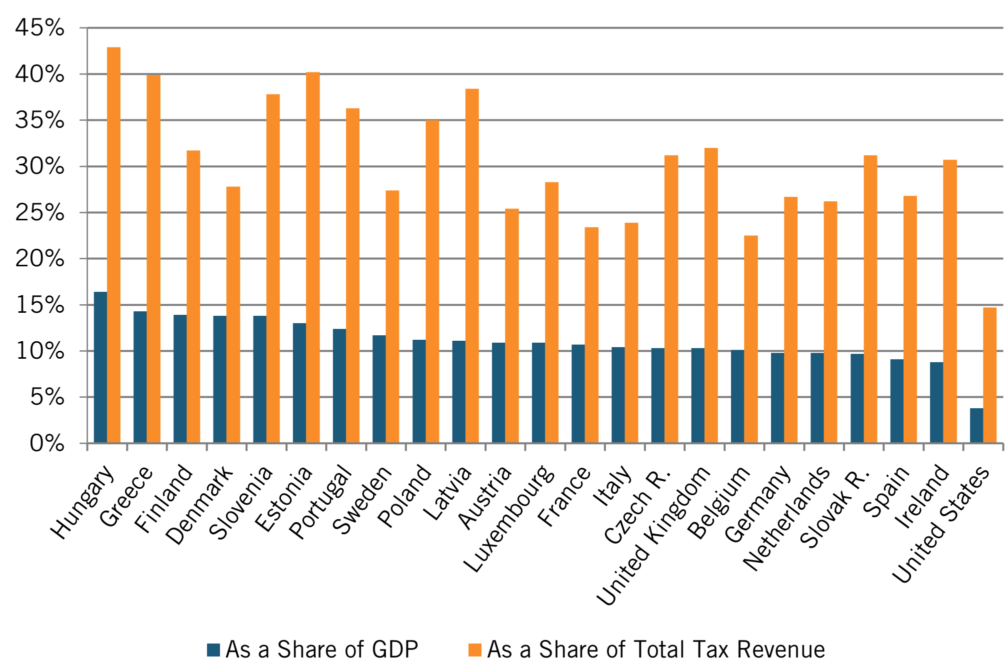
Land use regulation also leads to reduced ICT benefits, particularly in the retail sector. A number of studies in the United Kingdom, as well as in mainland Europe, have found that regulations regarding the use of land can prevent retail stores from attaining economies of scale, and ICT has been the main enabler of increasing retail scale.[169] Cheshire et al., for example, found that rules prohibiting larger retail stores in the United Kingdom may have held back productivity in that sector by as much as 25 percent.[170]

Tariffs and Taxes

Companies make decisions about capital investment on the basis of return on investment. If the return is low due to factors such as product market regulations, labor market regulations, or land use regulations, the number of projects that will exceed firms' hurdle rates will be smaller. But policies that raise prices for capital goods will lead to fewer projects exceeding their hurdle rates. Conversely, policies that reduce the after-tax cost of capital goods will increase the number of investable projects—although taxes and tariffs also raise the cost of ICT products.

Because the EU signed onto the 1997 Information Technology Agreement (ITA), an international agreement to reduce ICT barriers, its tariffs on ICT imports are low.[171] However, in addition to tariffs, high taxes add costs for businesses and consumers. Europe has significantly higher consumption taxes than the United States. Rates for the value-added tax are set to be harmonized across Europe at around 20 percent, although they appear to be a bit lower than that in practice, averaging between 10 and 16 percent in different countries for a basket of goods.[172] This is compared with an average of 5.8 percent for the same basket of goods in the United States. Consumption-tax revenue in Europe makes up a much larger proportion of both overall tax revenue and GDP than in the United States, despite Europe's higher overall tax rates (figure 20). These taxes have a clear impact on prices: A recent cross-country study found that on average, in the United States 14 percent of the purchase price of an Apple iPad goes to taxes, while in European countries the percent going to taxes ranges between 16 and 19 percent.[173] Although these taxes are sometimes justified as "luxury" taxes, most ICT goods are in fact not luxury goods, but rather "pro-sumer" capital goods that spur productivity.

Figure 20: General consumption-tax revenue in the United States and European Union as a share of total tax revenue and GDP, 2014[174]



Higher taxes on ICT products do not raise ICT costs for businesses in Europe, because under the EU VAT system, businesses can recover tax expenses for business inputs, including investment. However, higher taxes on ICT consumption do discourage ICT use by consumers, making it more difficult for businesses to use ICT to adopt customer-facing productivity increases.

Europe's high consumption taxes may only affect business investment decisions indirectly, but corporate tax policies play a more direct role. Recently, several European countries have proposed data taxing directed specifically at large Internet companies such as Google and Facebook.[175] Higher taxes on ICT-producing companies could raise the price of ICT goods and services for everyone. Moreover, the existing proposals are poorly designed and could easily penalize or deter start-ups. For example, the proposed French tax on data collection would tax companies based on the number of users they collect data on, apparently with no regard to the actual market value of that data.

From 2012 to 2017, digital ad revenues grew 93.5 percent in the EU, and 140.4 percent in the United States. If EU digital ad revenue had grown at the same rate as in the United States, an additional 11.6 billion euros would be flowing annually to the EU digital ecosystem.

Another important channel through which tax policies influence investment is depreciation rates—the rates at which corporations can write off capital investments for tax purposes.[176] Accelerated depreciation decreases tax revenues in the United States by 6.6 percent, and thus comprises a substantial incentive to invest in new equipment, including ICT equipment.[177] Moreover, recent U.S. tax reform legislation permits firms to amortize all investments made within the first year. Depreciation rates in different countries also vary widely between types of ICT. Compared with most European countries, for example, the United States allows faster depreciation of ICT assets like computing equipment (one to two years), although its rate for communication equipment is much closer to average.[178] Moreover, the recent U.S. tax reform legislation allows firms to expense in the first year all capital equipment expenditures. This provision is for five years but is likely to be extended. A number of fast-growing EU-13 countries such as Lithuania and Slovenia have increased the speed at which companies can depreciate ICT investments.[179] Over time, these rate differences could have significant effects on ICT investment and thus accumulated ICT capital stock. Unfortunately, this is not a well-developed body of research, so further work is necessary to determine whether ICT capital depreciation rates have a significant effect on investment.

Management Differences

While regulations and taxes affect the return on ICT investments, in any given environment, firms still have investment choices. These choices are in part dependent on management practices that vary not only between firms but among nations. Management practices are another reason European firms appear to have gained less from ICT than firms in the United States. EU firms have been less willing or able to reengineer business processes around the use of ICT. Such restructuring is a crucial step in getting full productivity benefits from ICT. For example, laser scanners not only boost checkout-clerk productivity, they also allow retailers to reengineer their entire supply chain. Bresnahan, Brynjolfsson, and Hitt found that firms that embrace "new-economy" management practices (e.g., decentralized decision-making) and at the same time invest significantly in ICT, outperform other firms.[180] As they noted, "Firms do not simply plug in computers or telecommunications equipment and achieve service quality or efficiency gains. Instead they go through a process of organizational redesign and make substantial changes to their service or output mix."[181] Polling of business executives around the world confirms this analysis, as 97 percent believe technology alone would not raise productivity in their firm to the highest level achievable unless it was accompanied by organizational changes.[182] These organizational effects on ICT end up facilitating more significant productivity gains than firms would achieve simply by optimizing individual processes.

Thirty-percent of U.S. firms listed increasing labor productivity as the most or second most important goal of their firm, compared with 25 percent of firms in the EU.

This theory has been strongly supported by evidence from Bloom, Sadun, and van Reenen, who examined differences in management techniques between U.S. and European firms both operating in Europe.[183] U.S. firms are considerably more likely to employ management practices that enable organizational changes that harness the benefits of ICT—and the authors attribute nearly half of the U.S.-EU productivity differential 1995–2005 to this "organizational capital." Furthermore, they found that "IT-using intensive" industries such as retail and wholesale had the greatest productivity benefits from better management practices. Previous work by Bloom and van Reenen also found that American management quality was better overall than European management across a range of management quality indicators.[184] These indicators show up in sourcing decisions as well: Outsourcing by U.S. firms is more likely to be driven by transformative strategies like reengineering processes, gaining access to new technology, and developing new analytical capabilities, whereas in Europe, the primary concern is straightforward cost cutting.[185] Similarly, Fabiano Schivardi and Tom Schmitz found that "Southern Europe's recent slowdown in productivity growth and the ensuing divergence with the rest of the OECD can be partially explained by the interaction between the IT Revolution and the inefficient management practices of Southern European firms."[186] Similarly, a recent study found that "the advantage of US companies in translating knowledge into productivity gains is not only driven by their higher concentration in high-tech industries, but also by their higher ability to translate R&D into productivity within those industries.[187]

Research has also found that the impact of ICT capital is greater in an organization when there are higher levels of investment in intangible capital.[188] This includes R&D, firm-specific human capital, and organizational structures. This may explain why, in five EU regions, the 20 percent of the most productive manufacturing firms that adopt ICT get even greater productivity benefits than less productive firms.[189]

A recent OECD study found "strong support for the hypothesis that low managerial quality, lack of ICT skills and poor matching of workers to jobs curb digital technology adoption and hence the rate of diffusion. Similarly, our evidence suggests that policies affecting market incentives are important for adoption, especially those relevant for market access, competition and efficient reallocation of labour and capital. Finally, we show that there are important complementarities between the two sets of factors, with market incentives reinforcing the positive effects of enhancements."[190]

Perhaps most interesting is that the importance of management practices to being able to take full advantage of technology adoption in a firm appears to be particularly important in the digital era. For example, Schivardi and Schmitz showed that before the IT Revolution

(1985 to 1995), there was no correlation between average management scores in a country and productivity growth. However, between 1995 and 2008, there was a strong positive correlation.[191]

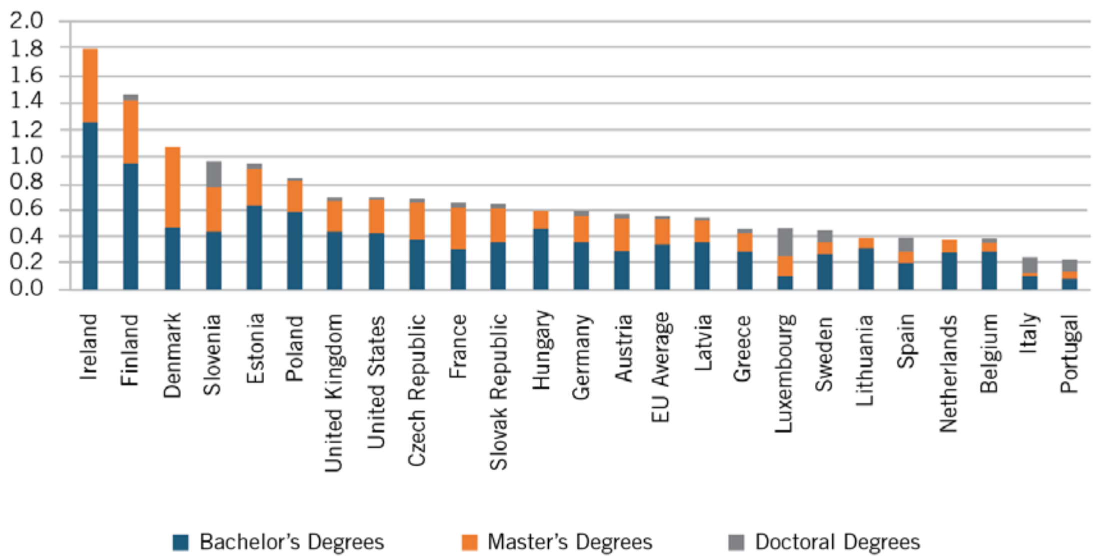
Finally, companies in the EU appear to place less emphasis on increasing productivity than do companies in the United States. Thirty percent of U.S. firms listed increasing labor productivity as the most or second most important goal for their firm, compared with 25 percent for firms in the EU. Likewise, 32 percent of firms in the United States made investments in organizational or business-process improvements greater than 5 percent of turnover, compared with 20 percent of EU firms.[192]

Such differences are obviously harder to influence through public policy than factors such as regulation and taxes, but governments can do certain things such as improving labor regulations, corporate governance laws, and workforce training.

Fewer ICT Skills

Europe also appears to lag behind the United States in ICT skills. OECD data shows the share of adults lacking basic computer skills is higher in many EU nations, including Belgium, Finland, Greece, Poland, Italy, Spain, and France than in the United States.[193] And increasing the provision of ICT training to low-skilled employees from a low level (Greece) to the sample maximum (Denmark) could boost the adoption rates of cloud computing and digital front-office technologies (such as customer relationship management) by around 7 percent in knowledge-intensive industries relative to other industries.[194] Moreover, in the United States in 2015, there were 0.44 computer science degrees awarded per thousand people, compared with 0.33 in the EU countries that reported data. While some nations, such as Ireland, Finland, and Denmark exceeded the United States, most other nations lagged behind (figure 21).

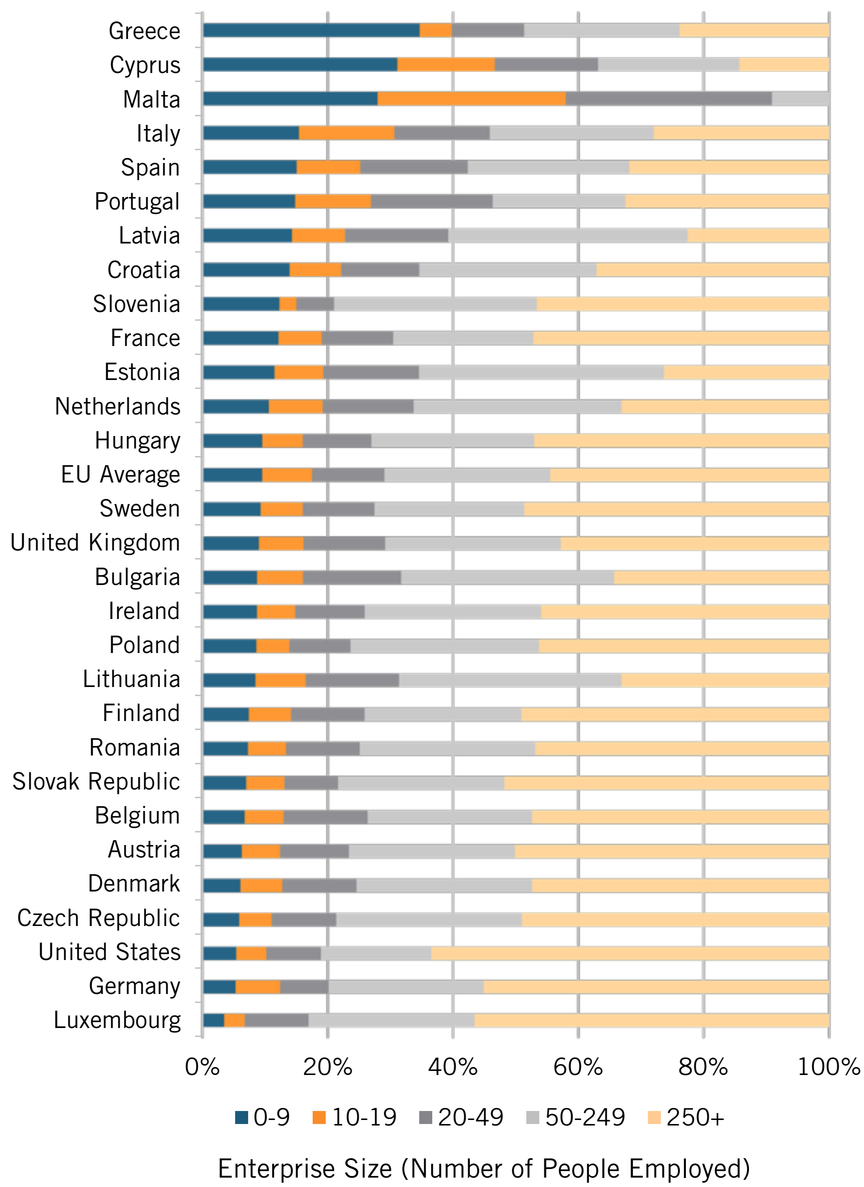
Figure 21: ICT graduates by level of degree per 1,000 workers, 2016[195]



Too Many Small Firms and Limited Market Integration

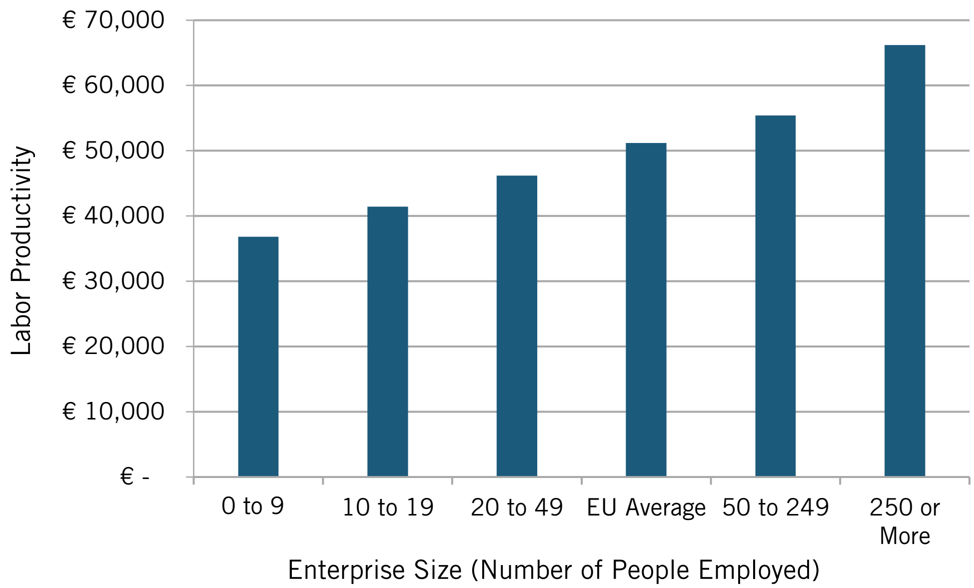
Two additional reasons European firms lag in their investment in ICT capital are related to scale. The first scale problem is with firm size. The United States has a higher percentage of workers employed by large firms than all European countries (figure 22). In particular, Greece, Cyprus, and other Mediterranean countries stand out as having an unusually high proportion of their employment in small firms.

Figure 22: Percentage of total workforce employed at enterprises by size, 2014[196]



In Europe, the economies with the highest productivity—Germany, Switzerland, and the United Kingdom—have the smallest proportion of workers in small firms, and some of the highest labor productivity rates.[197] Meanwhile, EU nations with the lowest productivity, such as Greece, have very low productivity, and the highest percentage of small firms in Europe (two-thirds of Greek firms have under 20 workers).[198] Larger firms are usually more productive, in part because they can take greater advantage of economies of scale when they invest in capital stock, including ICT.[199] As figure 23 shows, in Europe, the relationship between enterprise size and productivity is clear. [200]

Figure 23: Labor productivity and enterprise size in the European Union, 2015[201]



U.S. firms are considerably more likely to employ management practices that enable organizational changes that harness the benefits of ICT.

Firm size matters for the EU because larger firms are more likely to invest in ICT. This is because larger firms face fewer resource constraints and can more easily enjoy scale benefits of IT. For example, it can cost the same to develop an enterprise resource planning (ERP) system for a mid-size firm as for a large one, but the latter can amortize those costs over a larger revenue base. As Hitt, Wu, and Zhou have shown in their paper examining IT adoption by firms, ICT investments have high returns to scale because of their low marginal costs and higher fixed costs.[202] To be sure, the increased provision of software through cloud-based services may change that somewhat, but scale benefits are not likely to disappear, if for no other reason than most enterprise IT needs some customization—which raises fixed costs. This is why Schivardi and Schmitz showed IT adoption is positively correlated with firm size. They found that only 34 percent of Italian firms and 33 percent of German firms with between 10 and 49 employees had adopted ERP systems, while 79 percent and 85 percent of firms with over 250 workers respectively had adopted ERP. Lower, but still significant, differences existed for adopting customer relations management and supply-chain management systems.[203] They also found that reduced IT investment contributed between 28 percent (Italy), 39 percent (Spain), and 67 percent (Portugal) of the nations; falling behind faster Germany productivity growth, in part due to smaller firm size in these nations.

Regulation that favors small firms has been a significant hindrance to ICT investment in many European nations.[204] The firm-size problem ties into regulatory issues, particularly because labor-market regulation can limit the number of employees a firm chooses to employ.[205] France has a number of laws that apply only to businesses with 50 or more employees, which incentivizes firms to stay under the 50-worker threshold.[206] Land use regulations can also constrain both firm size, by preventing the entry of more efficient franchise-style firms, and establishment size, by prohibiting larger service-industry locations. Indeed, the European Commission's official policy is to size discriminate, stating, "Being SME-friendly should become mainstream policy. To achieve this, the 'Think Small First' principle should be irreversibly anchored in policy making from regulation to public service."[207] In general, European policies favoring small firms, and exempting them from the regulatory and tax burdens faced by larger firms, only serves to reduce European ICT adoption and resultant productivity than otherwise would be the case.

Europe's second challenge regarding scale is the issue of market size. While the EU economy is larger than that of the United States, in practice, it is much less integrated. Therefore, the market for a firm's products or services is more limited, often to only the nation in which it is based.[208] Because the United States effectively has a much larger market, there are greater potential returns on ICT investments for U.S. firms, again because of the high fixed costs relative to marginal costs in many ICT capital investments. This is why van Ark and Jaeger noted, "Limited scale effects in Europe, related to fragmented markets and limited impacts from ICT utilization might have played a larger role [in lower productivity growth] than in the United States especially during the first decade of the century."[209]

Finally, a strong capacity for creative destruction becomes increasingly important as countries become more advanced (Acemoglu et al., 2006). However, the process of creative destruction clearly works much less well in many European countries than in the United States, as is witnessed by processes of entry and exit of firms and the much stronger growth rate of successful American start-ups.[210] Moreover, as Veugelers found, "Firms in the US grow and shrink more rapidly than in European countries, which have a much larger share for which employment does not vary much (up or down)."[211]

What About the ICT-Producing Sector?

Since the late 1990s, when the United States' lead in information technology became apparent, Europe has tried to play catch-up, but more by trying to build a stronger ICT-producing sector than by figuring out how to boost ICT adoption by firms. Despite these efforts, Europe has largely failed. In 2015, the United States got over 6 percent of business value added from the ICT-producing sector, while Europe got only 4.7 percent.[212] While Sweden and Finland have larger ICT-producing sectors in terms of value added than the United States, most major European countries, including France and Germany, have smaller ICT sectors—and on average Europe gains less of its GDP from its production of ICT.[213]

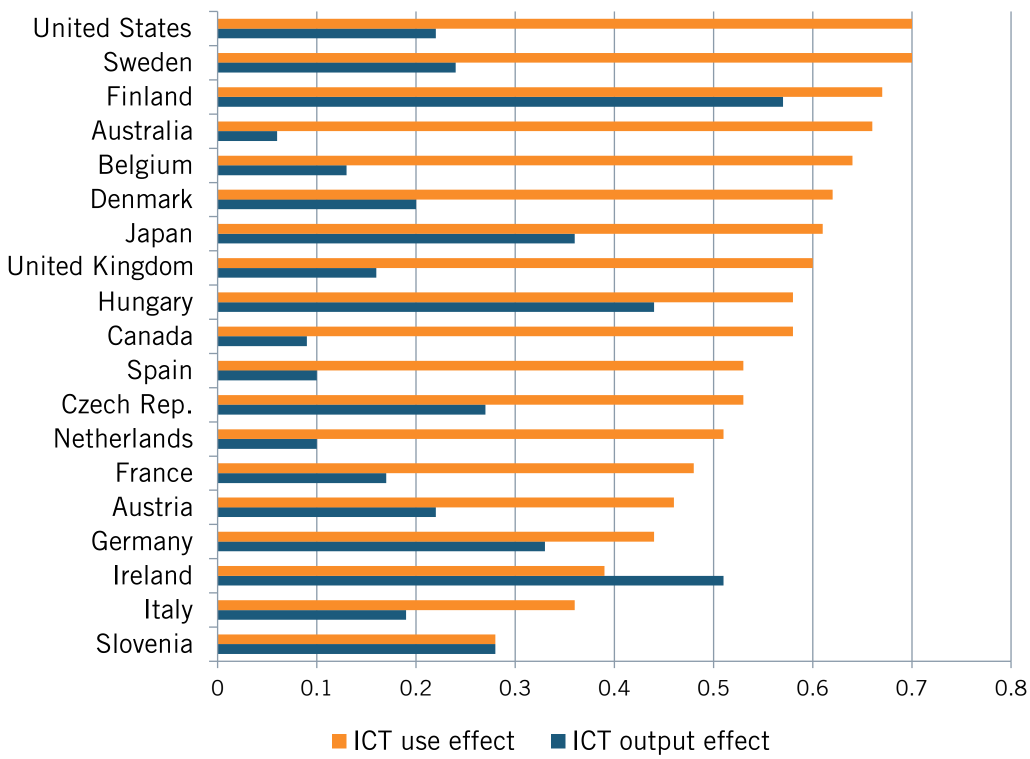
However, the large gains are to be realized not from production of ICT—which will be much more difficult for Europe to achieve in the presence of strong U.S. and Asian competitors (particularly China)—but from adoption. Despite this, the European Commission and many individual European governments have placed more attention on building IT companies than on spurring IT use.[214] See for example this statement adopted in 2012:

> The European Commission tabled on 26 June 2012 its strategy to boost the industrial production of KETs [key enabling technologies]-based products, e.g. innovative products and applications of the future. The strategy aims to keep pace with the EU's main international competitors, restore growth in Europe and create jobs in industry, at the same time addressing today's burning societal challenges.[215]

Along similar lines, many European countries have recently focused on building their own domestic data centers, rather than ensuring European ICT users have access to the cheapest and highest-quality cloud data providers. And more broadly, the widespread criticisms of U.S. IT leaders—disparagingly termed GAFA [Google, Apple, Facebook, and Amazon]—coupled with efforts to tax, regulate, and prosecute them, reflects, rather than a desire to catch up and embrace the digital economy, a sour, defeatist view that believes not only can Europe not be a digital innovator, but that maybe there is something wrong with being one.[216]

European policies favoring small firms and exempting them from the regulatory and tax burdens faced by larger firms only serves to reduce European ICT adoption and resultant productivity than otherwise would be the case.

Figure 24: ICT use and ICT output effects on GDP (2000 to latest year, percentage points per annum)[217]



This focus on the ICT-producing sector appears to be misplaced. Rohman found that the beneficial effects of the ICT sector for the broader European economy declined after the year 2000.[218] Other evidence has shown that most of the productivity gains from ICT are due to ICT-using sectors. For example, Bryne and Corrado estimate that for the United States, over the decade to 2014, ICT use contributed 1.1 percentage points per year to growth, while ICT production contributed just 0.3 percentage points per year.[219] The European Commission has also written that "Digitisation of all sectors will be needed if the EU is to maintain its competitiveness, keep a strong industrial base and manage the transition to a smart industrial and services economy. 75% of the value added by the Digital Economy comes from traditional industries, rather than ICT producers…"[220] To a large degree, this is because ICT-using sectors, like market and nonmarket services, make up a much larger part of developed-country economies than ICT-producing sectors, so productivity gains in those sectors have a much larger effect on the whole economy (figure 24).[221]

There are many reasons behind policymakers prioritizing ICT industry growth over ICT usage. One is simply a misunderstanding of the true sources of ICT-related growth: With the great success of some of the world's ICT leaders such as Apple, Google, Intel, and Samsung, it seems logical to try to replicate that success. A second reason appears to be an aversion to ICT adoption-based growth because of the fear it will lead to disruption and perhaps job loss in individual enterprises. Emblematic are comments from French president Emmanuel Macron, who stated that AI should be "totally federalized…[because] this kind of disruption can destroy a lot of jobs."[222] Certainly, job disruption is painful—and it is understandable for policymakers to be concerned—but the reality is that Europe needs technology-led productivity if it is to avoid further economic stagnation. Moreover, the view that technology is the enemy of job growth has been thoroughly discredited both by history and economics.[223]

WHAT DOES EUROPE NEED TO DO?

Europe's central economic challenge over the next quarter century will be to raise productivity growth rates. Faster productivity growth will ensure Europe's production will be able to support a growing share of the population not in the labor force, its firms will maintain global competitiveness, and its governments will have the ability to raise needed revenues without raising taxes.

The next production revolution holds the promise of enabling the creation of a set of tools organizations can use to increase the currently anemic rate of EU productivity growth. It is not unreasonable, especially if Europe adopts pro-innovation policies, to expect that annual European labor productivity growth rates could increase to perhaps 3 percent. If Europe can achieve these growth rates, it will mean significantly faster income growth (a doubling of per capita incomes in 27 years).[224]

Its central opportunity will be to take advantage of the ICT engine to shift to a higher-productivity path. To do this, however, policymakers will need to make widespread adoption of ICT a policy priority across the entire EU economy. While it is beyond the scope of this report to lay out a detailed ICT policy blueprint for Europe, there are at least seven key principles policymakers should follow if the EU and EU nations are to fully benefit from ICT.

1. Focus on Raising Productivity

Many European officials see increasing jobs, even if it means reducing productivity, as the top priority.[225] As long as European policymakers continue to place job creation above productivity it will be difficult to close the productivity gap with the United States. To be clear, in the aftermath of the Great Recession it was important to focus on job growth. But now the focus needs to shift more to productivity growth. Moreover, as the scholarly literature shows, there is no negative relationship between higher productivity and job growth.[226] Europe can enjoy both.

To effectively drive productivity-enhancing policies, nations need a dedicated productivity agency or commission. The European Productivity Agency Commission was established after World War II but was eliminated in the early-1960s, and its functions moved to other agencies. Europe does have a European productivity network, but it is merely a group of national productivity centers—and its focus goes beyond productivity.[227] As such, the European Commission should form an internal group that is focused exclusively on productivity, and policies to advance it.

2. Focus on Across-the-Board Productivity Growth, Particularly Through Greater Use of ICT

EU economic policymakers face the key choice of whether to focus their strategies on targeting a few key technology sectors—in part through trade policy (e.g., higher tariffs on imports) and regulations (e.g., the push for the "European cloud")—or on spurring widespread ICT adoption by all firms in all industries in Europe. The choice should be clear: Even in the United States, the ICT sector itself employs a small percentage of the workforce that is not growing. Moreover, for most countries, the majority of productivity gains from ICT have originated in other sectors and not from the growth of ICT sectors.[228]

The European Commission should form a group within the Commission focused exclusively on productivity and policies to advance it.

Moreover, if EU policymakers want to grow their own digital firms, they would be much better off focusing on the future, and not the past. No matter how much Europe wants to regulate, tax, and prosecute leading U.S. Internet companies, it will not win in these areas. The winners in Internet search, social media, e-commerce, smartphones, and other related areas are largely already established. And only an effort like that of China—using massive, unfair subsidies, intellectual property theft, and closed markets—can possibly gain sizeable market share in these areas. Europe would be much better off focusing on the industries of the future, not the recent past, and building on existing core competencies. For Europe, this means building on Europe's global strength in mechanical engineering and doubling down on the relationship between software and physical devices—what often is termed Industry 4.0—but should be seen as much more than embedding intelligent devices in manufacturing.

3. Actively Encourage Digital Innovation and Transformation of Economic Sectors

The private sector will drive much of digital transformation, but government can and should play a supportive role. Economists have long argued that businesses underinvest in research, which is the rationale for governments instituting research grants and R&D tax incentives. Economists have also documented significant market failures around IT investment, including network externalities and "chicken-or-egg" issues that slow digital transformation absent smart and supportive public policies.[229] Health care is a leading example. Success for any individual health organization that embraces a digital business model depends on other health organizations, and also patients, embracing the digital model. Such chicken-or-egg and network-externality issues exist in a host of industries, including transportation, real estate, government, and education—as well as in a host of technology industry areas, such as the industrial Internet. In these cases, EU governments should use a wide array of policy levers, including tax, regulatory, and procurement policies, to spur greater ICT adoption.

Moreover, government officials at all levels can and should lead by example by leveraging their own ICT efforts to achieve more effective and productive public-sector management and administration. Among other things, this means government should not only actively promote e-government, but also look to how ICT can be used help solve a wide array of pressing public challenges. In this regard, ICT can be a key public policy tool, alongside tax, procurement, and regulation.[230]

4. Use Tax Policy to Spur ICT Investment

It is only through investment that ICT innovation is diffused throughout the economy. For this reason, public policies should focus on spurring additional investment by organizations in the latest-generation ICT. Policymakers should minimize, if not eliminate, taxes on ICT investments, including broadband telecommunications, Internet usage, and data. They should allow companies to more rapidly depreciate ICT investments for tax purposes, including allowing firms to expense them in their first year. For example, in 2016 Italy introduced a tax credit for capital investments related to Industry 4.0, aimed at digitalization, automation, and data exchange for production in manufacturing.

The European Commission should do away with the "adequacy" standard in the GDPR and instead replace it with a duty-of-care provision.

Some economists might question such policies, arguing that such tax incentives should only go to investments in areas like R&D, where companies seldom capture all the benefits. However, because ICT transforms organizations and leads to innovations within other organizations, it operates in the same way as research, with high spillovers that may be taken advantage of by other organizations.[231] In such an environment, the socially optimal amount of investment will lag behind actual investment. As such, it makes sense for the tax code to spur additional ICT investment, or at least avoid having the tax code penalize ICT investment.

5. Create Larger Markets for EU Firms

ICTs benefit from economies of scale. This means the larger the market the easier it can be for an organization to recoup its ICT investments. The EU has been advancing frameworks for better intra-EU digital compatibility and access through the Digital Agenda for Europe's Single Digital Market initiative.

These are steps in the right direction—but Europe needs to go further, particularly to create EU-wide markets for traded service sectors.[232] In particular, many professional services have national or subnational barriers to entry based on ensuring quality of service. While these barriers may serve important safety or quality goals, they may also function as barriers to competition, and are not always worth their costs in public welfare.

Finally, in an era of increasing trade tensions, policymakers should continue to push for deeper transatlantic integration. Some version of the Transatlantic Trade and Investment Partnership (TTIP) would significantly expand markets for many European firms by reducing nontariff barriers in the United States and increasing the ability of European companies to invest there. These larger markets would increase the return on investment on more ICT projects for firms in the EU.

Creating larger markets also requires enabling cross-border data flows through provisions such as the Privacy Shield because if Europe decides EU data cannot flow to the United States, it is possible the United States would pass a similar rule prohibiting EU firms in the United States from moving data to Europe. Such a provision would hurt many EU firms, including those in "traditional" industries such as automobile manufacturing, retail, and finance.[233] But for most firms, there is no reason for it from a privacy perspective.[234]

In fact, the European Commission should do away with the "adequacy" standard in the GDPR and instead replace it with a duty-of-care provision. When it comes to handling data, companies doing business in Europe should be responsible for the actions of both their agents and business partners, regardless of where they are located. The EU should exempt companies doing business in the EU (or those that have designated a legally responsible business agent in the EU) from the adequacy requirement and clarify that the new General Data Protection Regulation hold them legally responsible for any failure to protect the personal data of citizens, regardless of whether that failure is the fault of the company in the EU, or an affiliate, or a business partner in another nation. In other words, European protection would travel with the data, regardless of where that data travels. Companies doing business in the EU would then have a very strong incentive to insist their business partners outside of the EU adhere to the EU's privacy protections, because EU citizens could seek remedies from companies in the EU for any privacy violations.

Policies that lead to smaller firm size in an economy hurt productivity and income growth.

6. Reduce Preferences for Small Businesses

Europe overemphasizes in rhetoric and in policy the role of small firms in the economy.[235] For many policymakers, small firms have come to represent everything good in the economy. Yet, on average, large firms are more productive, pay higher wages, injure their workers less, are more innovative, and export more.[236] This is not to say small firms do not add value. Indeed, new firms that grow quickly do create a significant share of net new jobs. But the large majority of small firms stay small, particularly in Europe where firm size is much more stable than in the United States.[237]

Preferences for small businesses can take two forms: active policies to provide special benefits, and discriminatory policies that place tax and regulatory burdens only on large businesses. The former policies, unless carefully targeted to potential high-growth "gazelle firms," simply keep the share of the economy produced by small businesses larger than it otherwise would be.[238] The latter policies not only slow the growth of larger firms, they can slow the growth of smaller firms that do not want to lose their special entitlements for being small if they grow beyond the threshold.[239] One example is France's "anti-Amazon" law, which prohibits discounts on books and free shipping, because it raises prices for books from more efficient e-commerce channels, thereby limiting productivity growth in this sector.[240]

7. Embrace a Light-Touch Regulatory Framework

Maximizing the economic and societal benefits from ICT requires policies that support ICT adoption's role at the center of economic policy—and just as important, avoiding policies that harm this goal. All too often, well-intentioned policymakers are willing to consider regulations that slow or negatively affect the adoption of digital technologies. Due to emerging "data nationalism"—the idea that data is more private and secure when it is stored within a country's borders—one of the areas currently most at risk is digital trade, which countries often pursue as part of a "digital protectionism" strategy that includes discriminatory regulations to favor local firms and production.[241] For example, restrictions on intra-European Union transfers of data still exist: The Czech Republic restricts transfers of data on unemployed persons; France restricts data flows on defense and national security grounds; Germany restricts transfers of tax and business data; and Luxemburg restricts transfers of personal and financial data.[242] However, as to the former, local data storage requirements do not increase commercial privacy or data security. The reason is simple: A firm doing business in a country is subject to that country's laws, regardless of where it stores data. In effect, the data privacy and protection rules travel with the data. Agreements such as the European Union-United States Privacy Shield is another way to assure this is the case. Ultimately, the result of limits on cross-border data flows will be increased costs of ICT services for firms in Europe, thereby reducing their ICT adoption and productivity.

Privacy regulations are similar. Overly stringent privacy rules limit the ability of enterprises to obtain these gains.[243] As ITIF's Center for Data Innovation has written, the GDPR will make AI adoption by enterprises in Europe more difficult.[244] As such, national data regulators should work to ensure GDPR implementation is as innovation-friendly as possible. Similarly, as the Commission and national governments consider future privacy regulations, such as the e-Privacy regulation, it should work to narrow the scope of the regulation in order to prevent it from applying to most IOT devices or business-to-business interactions.[245]

Europe should also be careful to not "kill the goose that laid the golden eggs," by overregulating Internet platforms that provide value to many EU businesses and consumers.[246] Likewise, taking a light touch to broadband regulation, including rules regarding unbundling (e.g., lifting unbundling requirements where there are at least two providers within a geographic area), net neutrality,[247] and limits on ISP consolidation,[248] will help EU broadband catch up to the United States.

On a more local scale, city regulations have been keeping the ride-coordination service Uber from making inroads in Europe.[249] European cities need to find solutions that harness the benefits of technology and avoid rules that lock themselves into less-productive producers.

8. Help Workers Make Transitions

If Europe is to avoid a populist, neo-Luddite backlash against the next production revolution, policymakers will need to take greater and more effective steps to help regions and individuals at risk from technology disruption.

One place to start is with better help for lagging regions. Some workers who lose their jobs from new technologies can and will move to regions where employment growth is stronger, but not all workers are willing or able to do so. As such, smart policies and programs to spur growth in lagging regions can help minimize social disruption from the next production revolution.

Europe should be careful to not "kill the goose that laid the golden eggs" by overregulating Internet platforms that provide value to many EU businesses and consumers.

But the biggest challenge will be to help individual workers make successful transitions. More European nations should embrace the concept of "flexicurity," as Scandinavian nations have, which commits not to ensuring workers will never get laid off, but rather to minimizing the number of workers at risk; and then, for those who are laid off, providing support so they can make successful and expeditious transitions. Policies limiting layoffs only postpone the inevitable. Likewise, providing laid-off workers with very generous and long-term benefits would not only help ensure higher unemployment rates, but also lead to more workers being out of the labor market for long periods of time, hurting the very workers the benefits are intended to help—for the longer a worker is out of the labor force, the harder it is for him or her to re-enter. Rather the goal should be finding a balance between being overprotecting and too severe.

To do that, policymakers should adopt some of the world's best-in-class operational models, such as Singapore's SkillsFuture program. The lessons from Singapore are fourfold. First, government policy needs to make a major commitment to skill development and workforce transition. Second, such efforts need to be closely linked to employers and markets, including through training vouchers and credits. Germany has done an excellent job in this regard with its longstanding and widespread employer-supported apprenticeship system. Third, such efforts need to be much more flexible and take full advantage of advanced information technology tools. Finally, incremental changes in existing institutional arrangements will not be enough. If policymakers are to respond effectively to the challenges of a more turbulent labor market, they will need to drive significant institutional reform, particularly in the high school and higher education sectors; provide more support for institutions focused on technical training; and provide skills valued by employers.

European nations may want to focus on several areas. The first is enabling more workers to obtain better skills and other competencies so that if they are dislocated by technology they will be better positioned to make a successful transition. One key is to shift the education system, particularly at the high school and postsecondary levels, toward an increased focus on teaching both "21st century skills" such as teamwork, analytical skills, critical thinking, and more technical skills.

CONCLUSION

Europe has the potential to raise productivity significantly if it fully embraces the use of ICT. Some progress has been made through the implementation of the Digital Agenda. But productivity rates continue to lag behind those of the United States in the majority of EU countries. This is thanks to public policies and business practices in the United States that are more conducive to ICT use: better management, higher levels of ICT investment (particularly in ICT-using sectors), lower taxes on ICT products, and larger economies of scale at both the firm and market levels. Instead of seeing ICT adoption as a worldwide competition for the next new Silicon Valley, Europe needs to focus on where ICT can make the most difference: ICT use. This is a path the United States has already taken and proven to be successful—and Europe would prosper by following its lead.

ENDNOTES

1. This is an update of the original ITIF report published in 2014. Where available, the report has been updated to reflect the most recent data available; Robert Atkinson and Ben Miller, "Raising European Productivity Growth Through ICT" (Information Technology & Innovation Foundation, June 2014), https://itif.org/publications/2014/06/02/raising-european-productivity-growth-through-ict.
2. OECD. Stat, (Productivity and ULC by Main Economic Activity; Accessed July 20, 2018), https://stats.oecd.org/Index.aspx?DataSetCode=PDBI_I4.
3. Ben Miller and Robert D. Atkinson, "Digital Drag: Ranking 125 Nations on Taxes and Tariffs on ICT Goods and Services" (Information Technology and Innovation Foundation, October 2015), https://itif.org/publications/2014/10/24/digital-drag-ranking-125-nations-taxes-and-tariffs-ict-goods-and-services.
4. Robert D. Atkinson and Michael Lind, *Big is Beautiful: Debunking the Myth of Small Business,* (Massachusetts: The MIT Press), Chapter 3.
5. Stuart Macdonald, Pat Anderson, and Dieter Kimbel, "Measurement or Management?: Revisiting the Productivity Paradox of Information Technology," (Vierteljahrshefte zur Wirtschaftsforschung), https://www.diw.de/documents/publikationen/73/38739/v_00_4_9.382949.pdf.
6. Robert Atkinson, "Don't Fear AI," *European Investment Bank,* June 15, 2018, http://www.eib.org/essays/artificial-intelligence?mc_cid=8dec0cd27b&mc_eid=0ac4593ac6.
7. Daniel Castro and Alan McQuinn, "Cross-Border Data Flows Enable Growth in All Industries" (Information Technology and Innovation Foundation, February 2015), http://www2.itif.org/2015-cross-border-data-flows.pdf?_ga=2.14621431.1792391832.1529934284-1559993869.1449863882.
8. Robert D. Atkinson and Michael Lind, *Big is Beautiful, (*Massachusetts: The MIT Press), Chapter 3.
9. The Conference Board, Total Economy Database: January 2014 (total GDP [EKS], labor productivity per hour worked [EKS]; accessed July 25, 2018), http://www.conference-board.org/data/economydatabase/; author calculations following Marcel P. Timmer et al., "Productivity and Economic Growth in Europe: A Comparative Industry Perspective*," International Productivity Monitor* 21 (2011), 3–23.
10. The Conference Board, Total Economy Database.
11. Ibid. (Total GDP and Total annual hours worked).
12. Ibid.
13. Ibid.
14. Ibid.
15. OECD. Stat, (Productivity and ULC by Main Economic Activity; Accessed July 20, 2018), https://stats.oecd.org/Index.aspx?DataSetCode=PDBI_I4.
16. Ibid. Note that EU-28 productivity actually decreases due to the less-productive EU-13 increasing their share of GDP.
17. While it is likely that actual Irish enterprise productivity grew faster than U.S. enterprise productivity, measured overall productivity growth appears to be artificially inflated, in part by how foreign profits from tax inversions are treated in GDP accounting. See: Cliff Taylor, "Ireland's GDP Figures: Why 26% Economic Growth is a Problem," *The Irish Times,* July 15, 2016, https://www.irishtimes.com/business/economy/ireland-s-gdp-figures-why-26-economic-growth-is-a-problem-1.2722170.

18. OECD. Stat, (Productivity and ULC by Main Economic Activity; Accessed July 20, 2018), https://stats.oecd.org/Index.aspx?DataSetCode=PDBI_I4.

19. Ibid. Authors' analysis.

20. OECD. Stat, (Productivity and ULC by Main Economic Activity; Accessed July 20, 2018), https://stats.oecd.org/Index.aspx?DataSetCode=PDBI_I4.

21. Ibid.

22. The Conference Board, Total Economy Database (Total GDP and Total annual hours worked; accessed April 30, 2018), https://www.conference-board.org/data/economydatabase/index.cfm?id=27762.

23. Robert D. Atkinson, "Competitiveness, Innovation and Productivity: Clearing up the Confusion" (Information Technology and Innovation Foundation, August 2013), http://www.itif.org/publications/competitiveness-innovation-and-productivity-clearing-confusion.

24. The Conference Board, Total Economy Database. This assumes 2.3 percent productivity growth from 1995 to 2017 compared to 1.41 percent from 1995 to 2007 and 0.60 from 2007 to 2017.

25. Ibid.

26. OECD StatExtracts (Short-Term Labour Market Statistics: Activity Rates, aged 55-65, all persons; accessed February 13, 2014), http://stats.oecd.org.

27. OECD StatExtracts, Country Statistical Profiles 2012 (elderly population 65+, population growth rates; accessed January 20, 2014), http://stats.oecd.org/Index.aspx?DataSetCode=CSP2012#.

28. Ibid.

29. Based on the EU-15 rate of growth of 0.8 from 2006-2013. This does not account for the aging of the population, which would lower growth even more.

30. Robert D. Atkinson, "Competitiveness Innovation and Productivity: Clearing up the Confusion" (Information Technology and Innovation Foundation, August 2013), http://www2.itif.org/2013-competitiveness-innovation-productivity-clearing-up-confusion.pdf.

31. See for example: Stephen Ezell and Robert D. Atkinson, "The Good, the Bad, and the Ugly of Innovation Policy" (Information Technology and Innovation Foundation, October 7, 2010), 27-30, http://www.itif.org/publications/good-bad-and-ugly-innovation-policy; James Manyika et al., *How to Compete and Grow: A Sector Guide to Policy* (McKinsey Global Institute, March 2010), http://www.mckinsey.com/insights/economic_studies/how_to_compete_and_grow.

32. Chad Syverson, "What Determines Productivity?," *Journal of Economic Literature* 49, no. 2 (June 2011): 326–65, doi:10.1257/jel.49.2.326.

33. OECD and Eurostat, *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data* (OECD, 2005).

34. Robert Atkinson and Ben Miller, "Raising European Productivity Growth Through ICT," op. cit.

35. Robert D. Atkinson, Stephen Ezell, Scott M. Andes, and Daniel Castro, *The Internet Economy 25 Years After .com* (Information Technology and Innovation Foundation, March 2010), http://www.itif.org/publications/internet-economy-25-years-after-com; Matthieu Pélissié du Rausas et al., "Internet Matters: The Net's Sweeping Impact on Growth, Jobs, and Prosperity" (McKinsey Global Institute, May 2011).

36. Robert D. Atkinson, *The Past and Future of America's Economy: Long Waves of Innovation that Power Cycles of Growth* (Northampton, Massachusetts: Edward Elgar, 2004).

37. Richard G. Lipsey, "Transformative Technologies in the Past Present and Future: Implications for the U.S. Economy and U.S. Economic Policy" (presentation at ITIF Breakfast Forum, July 15, 2008), http://www.itif.org/files/2008-07-15-lipsey.pdf.

38. Jason Dedrick, ViJay Gurbaxani, and Kenneth L. Kraemer, "Information Technology and Economic Performance: A Critical Review of the Empirical Evidence," *ACM Computing Surveys* 35, no. 1 (March 2003), 1.

39. For several of the numerous literature surveys, see: Dedrick et al., "Information Technology and Economic Performance," 12; Mirko Draca, Raffaella Sadun, and John van Reenen, "Productivity and ICT: A Review of the Evidence" (discussion paper no. 749, Centre for Economic Performance, August 2006), http://eprints.lse.ac.uk/4561/; Tobias Kretschmer, "Information and Communication Technologies and Productivity Growth: A Survey of the Literature," *OECD Digital Economy Papers*, no. 195 (2012), http://dx.doi.org/10.1787/5k9bh3jllgs7-en; M. Cardona, T. Kretschmer, and T. Strobel, "ICT and Productivity: Conclusions from the Empirical Literature," *Information Economics and Policy* 25, no. 3 (September 2013): 109–125, doi:10.1016/j.infoecopol.2012.12.002.

40. Jack E. Triplett and Barry P. Bosworth, "Productivity Measurement Issues in Services industries: 'Baumol's Disease' has Been Cured," *FRBNY Economic Policy Review* 9, no. 3 (2003): 23–33; see also Carol A. Corrado et al., "Sectoral Productivity in the United States: Recent Development and the Role of IT," *Productivity Measurement and Analysis* (OECD Publishing, 2008), https://www1.oecd.org/std/productivity-stats/44516351.pdf#page=437; Sophia P. Dimelis and Sotiris K. Papaioannou, "Technical Efficiency and the Role of ICT: A Comparison of Developed and Developing Countries," *Emerging Markets Finance & Trade* 47 (July 2, 2011): 40–53, doi:10.2753/REE1540-496X4704S303; Jason Dedrick, Kenneth L. Kraemer, and Eric Shih, "Information Technology and Productivity in Developed and Developing Countries," *Journal of Management Information Systems* 30, no. 1 (July 1, 2013): 97–122, doi:10.2753/MIS0742-1222300103).

41. Cesare Buiatti, Joao B. Duarte, Luis Felipe Sáenz, "Why is Europe Falling Behind Structural Transformation and Services' Productivity Differences Between Europe and the U.S." (working paper, Cambridge Working Papers in Economics: 1708, University of Cambridge, 2017), 36.

42. Sophia P. Dimelis, Sotiris K. Papaioannou, "Does Upstream Regulation Matter When Measuring the Efficiency Impact of Information Technology? Evidence Across EU and US Industries," *Information Economics and Policy* December 2017), vol. 41, 67-80.

43. Matthias Diermeier, Henry Goecke, "Productivity, Technology Diffusion and Digitization," *Wirtschaftsforschung an der Universität München, München*, 2017, vol. 18, 26-32.

44. John van Reenen et al., "The Economic Impact of ICT, SMART" (Centre for Economic Performance, 2010), http://www.ukn.inet-tr.org.tr/eu/DCR/cStudyTheEconomicImpactofICTLondonSchoolofEconomics.pdf.

45. For example, the OECD report *The Economic Impact of ICT* found that ICT (production and use) was responsible for 109 percent of the growth in labor productivity from 1996 to 2002. OECD, *The Economic Impact of ICT: Measurement, Evidence and Implications* (OECD Publishing, 2004), 96, http://www.oecd-ilibrary.org/docserver/download/9204051e.pdf?expires=1398953382&id=id&accname=ocid43017007&checksum=04B30D1BFC36E957BCFD995CCB443898. See also: Robert D. Atkinson and Andrew McKay, "Digital Prosperity: Understanding the Economic Benefits of the Information Technology Revolution" (Information Technology and Innovation Foundation, March 2007), http://archive.itif.org/index.php?id=34.

46. Dale W. Jorgenson, Mun S. Ho, and Jon D. Samuels, "A Prototype Industry-Level Production Account for the United States, 1947-2010" (presentation to the Final World Input-Output Database Conference,

Groningen, The Netherlands, April 2013), 24, http://www.worldklems.net/data/notes/jorgenson_ho_samuels.USProductionAccount.pdf.

47. Ibid., 30; David M. Byrne, Stephen D. Oliner, and Daniel E. Sichel, "Is the Information Technology Revolution Over?" (SSRN Scholarly Paper, March 27, 2013), 22, http://papers.ssrn.com/abstract=2240961; Chad Syverson, "Will History Repeat Itself? Comments on 'Is the Information Technology Revolution Over?'" *International Productivity Monitor* 25 (2013), 37–40.

48. S. Gilchrist, V. Gurbaxani, and R. Town, "Productivity and the PC Revolution" (working paper, Center for Research on Information Technology and Organizations, 2001); Robert K. Plice and Kenneth L. Kraemer, "Measuring Payoffs from Information-Technology Investments: New Evidence from Sector-Level Data on Developed and Developing Countries" (working paper, Center for Research on Information Technology and Organizations, 2001); Mika Maliranta and Petri Rouvinen, "Productivity effects of ICT in Finnish business" (discussion paper no. 852, Research Institute of the Finnish Economy, 2003).

49. Daniel J. Wilson, "IT and Beyond: The Contribution of Heterogeneous Capital to Productivity" (working paper no. 13, Federal Reserve Bank of San Francisco, 2004), 13.

50. Lorin M. Hitt and Prasanna Tambe, "Measuring Spillovers from Information Technology Investments" (proceedings of the 27th International Conference on Information Systems, Milwaukee, WI, 2006), 1793.

51. Ana Rincon, Michela Vecchi, and Francesco Venturini, "ICT Spillovers, Absorptive Capacity and Productivity Performance" (discussion paper, National Institute of Economic and Social Research, November 25, 2013), http://eprints.mdx.ac.uk/9992/.

52. For developing country literature, see: Dedrick et al., "Information Technology and Productivity in Developed and Developing Countries" for a cross-country study, or for specific examples see Geoff Walsham, "ICTs for the Broader Development of India: An Analysis of the Literature," *The Electronic Journal of Information Systems in Developing Countries* 4, 2010, http://www.ejisdc.org/Ojs2/index.php/ejisdc/article/view/665 and Jyoti Vig, "Information Technology and the Indian Economy" (PhD diss., University of Minnesota, March 2011), http://conservancy.umn.edu/bitstream/104630/1/Vig_umn_0130E_11796.pdf.
For public sector literature examples, see: Luis Garicano and Paul Heaton, "Information Technology, Organization, and Productivity in the Public Sector: Evidence from Police Departments," *Journal of Labor Economics* 28, no. 1 (January 2010), 167–201; Davide Arduini et al., "The Role of Technology, Organization and Contextual Factors in the Development of E-Government Services: An Empirical Analysis on Italian Local Public Administrations," *Structural Change and Economic Dynamics* 27 (2013), 177–189.

53. David M. Byrne, John F. Fernald, and Marshall B. Reinsdorf, "Does the United States Have a Productivity Slowdown or a Measurement Problem?" (BPEA conference draft paper, Brookings Institution, March 10–11, 2016), accessed March 8, 2016, http://www.brookings.edu/~/media/projects/bpea/spring2016/byrneetal_productivitymeasurement_conferencedraft.pdf.

54. Barry Eichengreen, "Why a Productivity Slump Can be a Harbinger of Better Times," *The Guardian,* December 10, 2015, https://www.theguardian.com/business/2015/dec/10/why-a-productivity-slump-can-be-a-harbinger-of-better-times.

55. Robert J. Gordon, *The Rise and Fall of American Growth,* (New Jersey: Princeton University Press, 2017).

56. Joseph A. Schumpter, *Capitalism, Socialism and Democracy*, (New York: Harper Perennial, 1942), 67.

57. Ibid, 68.

58. Ibid, 83.

59. Robert D. Atkinson, "Don't Fear AI," *European Investment Bank*, June 15, 2018, http://www.eib.org/en/essays/artificial-intelligence?mc_cid=8dec0cd27b&mc_eid=0ac4593ac6#2.

60. Daniel Castro and Joshua New, "The Promise of Artificial Intelligence," (Center for Data Innovation, October 2016), http://www2.datainnovation.org/2016-promise-of-ai.pdf.

61. Irving Waldawksy-Berger, "'Soft' Artificial Intelligence Is Suddenly Everywhere," *The Wall Street Journal*, January 16, 2016, http://blogs.wsj.com/cio/2015/01/16/soft-artificial-intelligence-is-suddenly-everywhere/.

62. Ibid.

63. Robert D. Atkinson, "'It's Going to Kill Us!' and Other Myths About the Future of Artificial Intelligence," (Information Technology and Innovation Foundation, June 2016), http://www2.itif.org/2016-myths-machine-learning.pdf?_ga=1.201838291.334601971.1460947053.

64. Daniel Bentley, "Why Ford Won't Rush an Autonomous Car to Market," *Fortune,* December 6, 2017, http://fortune.com/2017/12/06/ford-autonomous-cars/.

65. Rodney Brooks, "My Dated Predictions," *Rodney Brooks,* January 1, 2018, https://rodneybrooks.com/my-dated-predictions/.

66. Ibid.

67. Carlota Perez, *Technological Revolutions and Financial Capital,* (Massachusetts: Edward Elgar Publishing, 2002), https://www.amazon.com/Technological-Revolutions-Financial-Capital-Dynamics/dp/1843763311.

68. Desirée van Welsum, Willem Overmeer, and Bart van Ark, *Unlocking the ICT Growth Potential in Europe: Enabling People and Businesses* (European Commission Digital Agenda for Europe, 2013).

69. OECD, Statistics (Productivity, contributions to GDP growth; accessed May 1, 2018), http://stats.oecd.org.

70. EU KLEMS, "Growth and Productivity Accounts: Statistical Module, ESA 2010 and ISIC Rev. 4 Industry Classification," (2017), http://www.euklems.net.

71. Dan Corry, Anna Valero, and John van Reenen, "UK Economic Performance since 1997: Growth, Productivity and Jobs" (London School of Economics and Political Science, 2011), http://ideas.repec.org/p/ner/lselon/http--eprints.lse.ac.uk-47521-.html.

72. Peter Goodridge, Jonathan Haskel, and Gavin Wallis, "UK Innovation Index: Productivity and Growth in UK Industries" (discussion paper, Centre for Economic Policy Research, July 2012), 52, http://ideas.repec.org/p/cpr/ceprdp/9063.html.

73. Mika Maliranta, Petri Rouvinen, and Pekka Ylä-Anttila, "Finland's Path to Global Productivity Frontiers through Creative Destruction," *International Productivity Monitor* 20, no. 10 (2010): 68–84.

74. Among others, see: Shikeb Farooqui, "Information and Communication Technology Use and Productivity," *Economic Trends* 625 (December 2005); Chiara Criscuolo and Kathryn Waldron, "E-commerce and Productivity," *Economic Trends* 600 (November 2003): 53; Tony Clayton, "IT Investment, ICT Use and UK Firm Productivity," *Economic Trends* 625 (December 2005); Nicola Matteucci et al., "Productivity, Workplace Performance and ICT: Industry and Firm-Level Evidence for Europe and the US," *Scottish Journal of Political Economy* 52, no. 3 (2005): 359–86; Thomas Hempell, "What's Spurious, What's Real? Measuring the Productivity Impacts of ICT at the Firm-Level," *Empirical Economics* 30 (2005), 427–64.

75. Hal Varian, Robert E. Litan, Andrew Elder, and Jay Shutter, "The Net Impact Study: The Projected Economic Benefits of the Internet In the United States, United Kingdom, France, and Germany, Version 2.0" (Cisco Systems, Inc., January 2002),

http://www.netimpactstudy.com/NetImpact_Study_Report.pdf; Donald A. Johnston, Michael Wade, and Ron McClean, "Does E-Business Matter to SMEs? A Comparison of the Financial Impacts of Internet Business Solutions on European and North American SMEs," *Journal of Small Business Management*, 45, 3 (July 2007), 354-361.

76. Irene Bertschek, Helmut Fryges, and Ulrich Kaiser, "B2B or Not to Be: Does B2B E-Commerce Increase Labor Productivity?," *ZEW Discussion Papers*, no. 04-45 (2004), http://econstor.eu/bitstream/10419/24055/1/dp0445.pdf.

77. Juha-Miikka Nurmilaakso, "ICT Solutions and Labor Productivity: Evidence from Firm-Level Data," *Electronic Commerce Research* 9, no. 3 (2009), 173-81.

78. Philipp Koellinger, "Impact of ICT on Corporate Performance, Productivity and Employment Dynamics" (European Commission Enterprise and Industry Directorate General, December 2006), http://ec.europa.eu/enterprise/archives/e-business-watch/studies/special_topics/2006/documents/TR_2006_ICT-Impact_I.pdf.

79. Concetta Castiglione, "Technical Efficiency and ICT Investment in Italian Manufacturing Firms," *Applied Economics* 44, no. 14 (2012), http://www.tara.tcd.ie/bitstream/2262/62815/1/PEER_stage2_10.1080%252F00036846.2011.554374.pdf; Carlo Milana and Alessandro Zeli, "The contribution of ICT to production efficiency in Italy: firm-level evidence using data envelopment analysis and econometric estimations," *OECD Science, Technology and Industry Working Papers*, no. 2002/13 (September 2002), http://dx.doi.org/10.1787/101101136045; Carlo Milana and Alessandro Zeli, "Productivity slowdown and the role of ICT in Italy: a firm-level analysis" (OECD, 2004): 261-278, http://ssrn.com/abstract=700924.

80. Simona Iammarino and Cecilia Jona-Lasinio, "ICT Production and Labour Productivity in the Italian Regions" (European Urban and Regional Studies, February 7, 2013), doi:10.1177/0969776412464504.

81. Bronwyn H. Hall, Francesca Lotti, and Jacques Mairesse, "Evidence on the Impact of R&D and ICT Investments on Innovation and Productivity in Italian Firms," *Economics of Innovation and New Technology* 22, no. 3 (April 2013): 300–328, doi:10.1080/10438599.2012.708134.

82. J. Ruiz-Mercader, A. L. Meroño-Cerdan, and R. Sabater-Sánchez, "Information technology and learning: Their relationship and impact on organisational performance in small businesses," *International Journal of Information Management* 26, no. 1 (2005): 16-29.

83. Paul-Antoine Chevalier, Rémy Lecat, and Nicholas Oulton, "Convergence of Firm-Level Productivity, Globalisation and Information Technology: Evidence from France," *Economics Letters* 116, no. 2 (August 2012), 244–246, doi:10.1016/j.econlet.2012.02.022.

84. Roman Beck, Rolf Wigand, and Wolfgang Konig, "Integration of E-Commerce by SMEs in the Manufacturing Sector," *Journal of Global Information Management* 13, no. 3 (July-September 2005), 20-32, http://www.infosci-journals.com/downloadPDF/pdf/ITJ2901_fXBcKLEGfc.pdf.

85. Reinhilde Veugulers, et al, "Remaking Europe: The New Manufacturing as an Engine for Growth" (Bruegel, September 2017), 69 Reinhilde http://bruegel.org/2017/09/remaking-europe/.

86. M. Cardona, T. Kretschmer, and T. Strobel, "ICT and Productivity: Conclusions from the Empirical Literature," *Information Economics and Policy* 25, no. 3 (September 2013): 109–125, doi:10.1016/j.infoecopol.2012.12.002.

87. OECD, Statistics (National Accounts, 8A. Capital Formation by Activity ISIC Rev. 4; accessed May 1, 2018), http://stats.oecd.org/; OECD, Science, Technology and Industry Scoreboard 2017 (Figure 2.1.3. ICT Investment by Asset 2015), https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017/ict-investment-by-asset-2015_sti_scoreboard-2017-graph81-en.

88. Bart van Ark, “Recent Trends in Europe’s Output and Productivity Growth Performance at the Sector Level, 2002-2015,” *International Productivity Monitor,* 2017, vol. 33, 21; Kirsten Jäger, *The Conference Board and University of Groningen,* International Productivity Monitor, 2017, no. 33, 15.

89. Elena Ketteni, Theofanis Mamuneas, and Panos Pashardes, “Factors affecting the productivity of European Economies,” Cyprus Economic Policy Review, 2017, vol. 11, no. 2, 3-18 1450-4561.

90. This is calculated as the summed average of the ratio of 1,430 data points (12 years, 10 EU nations, and 12 industries).

91. Bart van Ark, Robert Inklaar and Robert H. McGuckin, “ICT and Productivity in Europe and the United States: Where Do the Differences Come From?,” *CESifo Economic Studies* 49, no. 3/2003 (2003): 295–318; OECD, Country Statistical Profile 2012 (Investment Data and Shares of ICT Investment in Total Non-residential GFCF; accessed January 28, 2014), http://stats.oecd.org/index.aspx?queryid=32480.

92. National Science Foundation, *Science and Engineering Indicators 2014* (Figure 6-7, ICT business and consumer spending as a share of GDP; accessed April 8, 2014), http://www.nsf.gov/statistics/seind14/content/chapter-6/fig06-07.xls.

93. National Science Board Science & Engineering Indicators, “ICT Business Spending as a Share of Selected Industry Categories for Selected Countries or Economies: 2016,” (accessed July 15, 2018), https://www.nsf.gov/statistics/2018/nsb20181/figures/fig06-04.

94. Ibid. Major European countries included in this chart are: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, and the United Kingdom.

95. OECD, *OECD Factbook 2013: Economic, Environmental and Social Statistics* (Science & Technology: Investment in ICT: Shares of ICT investment in non-residential gross fixed capital formation; accessed April 2, 2014) http://www.oecd-ilibrary.org/economics/oecd-factbook-2013_factbook-2013-en; World Bank, Databank: World Development Indicators (Gross Fixed Capital Formation as percentage of GDP); The Conference Board, Total Economy Database: January 2014 (Table 5; accessed April 2, 2014), http://www.conference-board.org/data/economydatabase/.

96. Ibid.

97. OECD, Science, Technology and Industry Scoreboard 2013 *(*Chapter 2: Figure 2.1.3 ICT investment by asset, 2000 and 2011; accessed January 28, 2014), http://dx.doi.org/10.1787/888932890599.

98. OECD, Statistics (National Accounts, 8A. Capital Formation by Activity ISIC Rev. 4; accessed May 1, 2018), http://stats.oecd.org/; OECD, Science, Technology and Industry Scoreboard 2017 (Figure 2.1.3. ICT Investment by Asset 2015), https://www.oecd-ilibrary.org/science-and-technology/oecd-science-technology-and-industry-scoreboard-2017/ict-investment-by-asset-2015_sti_scoreboard-2017-graph81-en.

99. Ibid.

100. OECD, “OECD Digital Economy Outlook 2017,” (Paris: OECD Publishing), chapter 4 https://doi.org/10.1787/9789264276284-en.

101. EU KLEMS, “Growth and Productivity Accounts: September 2017 release,” http://www.euklems.net/.

102. Ibid.

103. “Flash Eurobarometer 369: Investing in Intangibles: Economic Assets and Innovation Drivers for Growth,” EU Open Data Portal, https://data.europa.eu/euodp/data/dataset/S1034_369, 22.

104. EU KLEMS, "Growth and Productivity Accounts: September 2017 release," http://www.euklems.net/.

105. Robert B. Cohen, “How Software is Transforming the U.S. Economy Software Innovations and the Perpetual Development of New Software,” Economic Strategy Institute, July 5, 2017, 32.

106. EU KLEMS, "Growth and Productivity Accounts: September 2017 release," http://www.euklems.net/.

107. “Networked Readiness Index 2014,” World Economic Forum, accessed July 7, 2018, http://www.weforum.org/issues/global-information-technology.

108. Ibid.

109. Marcin Relich, “The impact of ICT on labor productivity in the EU,” (Information Technology for Development, 2017), 23:4, 706-722, https://doi.org/10.1080/02681102.2017.1336071.

110. Eurostat, “Cloud Computing Services,” (accessed July 28, 2018), http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_cicce_use&lang=en.

111. Eurostat, “E-commerce, Customer Relation Management (CRM) and Secure Transactions,” (accessed July 28, 2018), http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_bde15dec&lang=en.

112. Eurostat Statistics Explained, “Cloud Computing – Statistics on the Use by Enterprises,” (December, 2016), http://ec.europa.eu/eurostat/statistics-explained/index.php/Cloud_computing_-_statistics_on_the_use_by_enterprises.

113. Calculations based on table 4.1 and 4.2, Wen Chen, Thomas Niebel, and Marianne Saam, “Are intangibles more productive in ICT-intensive industries? Evidence from EU countries,” Telecommunications Policy 40, no. 5, (2016), 471–84.

114. Yuriy Gorodnichenko, Debora Revoltella, Jan Švejnar, Christoph T Weiss, “Resource Misallocation in European Firms: the Role of Constraints, Firm Characteristics and Managerial Decisions” (working paper, European Investment Bank, Luxembourg, 2018).

115. Ibid.

116. Bart van Ark, “The Productivity Paradox of the New Digital Economy,” *International Productivity Monitor,* 2016, no. 31.

117. Ibid, 11.

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

119. Ben Lorica, “The State of AI Adoption,” *O’Reilly,* December 18, 2017, https://www.oreilly.com/ideas/the-state-of-ai-adoption.

120. Teradata, “The State of Artificial Intelligence for Enterprises,” Enterprises, http://assets.teradata.com/resourceCenter/downloads/AnalystReports/Teradata_Report_AI.pdf.

121. This is based on a survey by McKinsey Global Institute conducted in 2017 of approximately 3,000 companies around the world.

122. “Reshaping Business with Artificial Intelligence: Closing the Gap Between Ambition and Action,” *MIT Sloan Management Review,* September 6, 2017.

123. McKinsey Global Institute, op. cit. endnote 121.

124. Dave Byrne & Carol Corrado, “ICT Prices and ICT Services: What Do They Tell Us About Productivity and Technology,” *International Productivity Monitor*, Centre for the Study of Living Standards, vol. 33, pages 150-181, Fall, 2017.

125. “Worldwide Public Cloud Services Spending Forecast to Reach $266 Billion in 2021, According to IDC” (IDC, July 18, 2017), https://www.idc.com/getdoc.jsp?containerId=prUS42889917.

126. Cisco, “Cisco Global Cloud Index: Forecast and Methodology, 2016-2017, (white paper, February 1, 2018), https://www.cisco.com/c/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.html.

127. Cisco, The Zettabyte Era: Trends and Analysis,” (June 2017), https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html.

128. Cisco, The Zettabyte Era: Trends and Analysis, June 2017.

129. Jordi Bata et. al, “Why is IPv6 Deployment Important for the Internet Evolution,” *Journal of Telecommunications and Information Technology*, https://www.researchgate.net/publication/228733500_Why_is_IPv6_Deployment_Important_for_the_Internet_Evolution.

130. “Comparison of IPv6 IPv6-Enabled Web Browsers in Different Countries,” 2018, https://www.vyncke.org/ipv6status/compare.php?metric=p&countries=be,us,gr,de,ch,lu,in,gb,ca,ee,ec,br,no,jp,tt,pt,fi,fr,my,pe,cz,au,nl,nz,ie,ro,zw,hu,si,gt,pr,kr,sa,vn,at,bo,pl.

131. “IPv6 Adoption Visualization,” Akamai, 2018, https://www.akamai.com/us/en/about/our-thinking/state-of-the-internet-report/state-of-the-internet-ipv6-adoption-visualization.jsp.

132. Yann Ménière and Ilja Rudyk, “The Fourth Industrial Revolution from the European Patent Office Perspective,” *Intellectual Property and Digital Trade in the Age of Artificial Intelligence and Big Data,* (International Centre for Trade and Sustainable Development (ICTSD): Geneva, Switzerland), 33; “The core technologies sector corresponds to the basic building blocks upon which 4IR technologies are built. It captures all 4IR inventions that directly contribute to the three established ICT fields: hardware, software, and connectivity. The second sector captures enabling technologies that complement the core technologies. It is subdivided into seven technology fields: analytics, user interfaces, 3D support systems, artificial intelligence, position determination, power supply, and security. The third sector, application domains, encompasses the final applications of 4IR technologies. It has been divided into six different domains: personal, home, vehicles, enterprise, manufacturing, and infrastructure.”

133. OECD Stat, (gross value added per person employed, business sector services by country; accessed July 19, 2018), https://stats.oecd.org/Index.aspx?DataSetCode=PDB_GR.

134. Timmer et al., “Productivity and Economic Growth in Europe.”

135. Ibid, 24.

136. Matilde Mas, “ICT and Productivity Growth in Advanced Economies” (working paper, University of Valencia and Ivie, 2010).

137. Cesare Buiatti, Joao B. Duarte, Luis Felipe Sáenz, “Why is Europe Falling Behind Structural Transformation and Services’ Productivity Differences Between Europe and the U.S.” (working paper, Cambridge Working Papers in Economics: 1708, University of Cambridge, 2017).

138. Ibid.

139. For a review of the literature, see: Federico Biagi, “ICT and Productivity: A Review of the Literature” (Institute of Prospective Technological Studies, Joint Research Centre, 2013), ftp://ftp.jrc.es/pub/EURdoc/JRC84470.pdf. See also: Christopher Gust and Jaime Marquez, “International Comparisons of Productivity Growth: The Role of Information Technology and Regulatory Practices,” *Labour Economics* 11, no. 1 (February 2004): 33–58, doi:10.1016/S0927-5371(03)00055-1.

140. Van Reenen et al., “The Economic Impact of ICT, SMART.”

141. Ibid.

142. McKinsey Global Institute, *Solving the Productivity Puzzle: The Role of Demand and the Promise of Digitization*, McKinsey and Company, (February 2018), https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Meeting%20societys%20expectations/Solving%20the%20productivity%20puzzle/MGI-Solving-the-Productivity-Puzzle-Report-February-22-2018.ashx.

143. Gilbert Cette, Jimmy Lopez, Jacques Mairesse, "Upstream Product Market Regulations, ICT, R&D and Productivity," *Income and Wealth,* February 2017, vol 63.

144. Ibid, 86.

145. Müge McGowan, Dan Andrews, and Valentine Millot, "Insolvency Regimes, Zombie Firms and Capital Reallocation," (working paper, Organisation for Economic Co-operation and Development, 2017), http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ECO/WKP(2017)31&docLanguage=En.

146. Avi Goldfarb and Catherine Tucker, "Privacy and Innovation" (National Bureau of Economic Research, 2011), http://www.nber.org/papers/w17124; Avi Goldfarb and Catherine E. Tucker, "Privacy Regulation and Online Advertising," *Management Science* 57, no. 1 (2011), 57–71.

147. James Campbell, Avi Goldfarb, and Catherine Tucker, "Privacy Regulation and Market Structure" (working paper, SSRN, 2011), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1729405.

148. Matthias Bauer et al., "The Economic Importance of Getting Data Protection Right: Protecting Privacy, Transmitting Data, Moving Commerce" (European Centre for International Political Economy / U.S. Chamber of Commerce, March 2013), https://www.uschamber.com/sites/default/files/legacy/reports/020508_EconomicImportance_Final_Revised_lr.pdf.

149. L. Christensen, et al., "The Impact of the Data Protection Regulation in the EU" (Intertic, 2013), http://www.intertic.org/new_site/wp-content/uploads/Policy%20Papers/CCER.pdf.

150. Booz and Company, "The Impact of E.U. Internet Privacy Regulations on Early-Stage Investment A Quantitative Study," 18, https://www.strategyand.pwc.com/media/uploads/Strategyand-Impact-EU-Internet-Privacy-Regulations-Early-Stage-Investment.pdf.

151. Anja Lambrecht, "E-Privacy Provisions and Venture Capital Investments in the EU," (2017), https://www.ceps.eu/sites/default/files/E-Privacy%20Provisions%20and%20Venture%20Capital%20Investments%20in%20the%20EU.PDF.

152. PwC, "IAB Internet Advertising Revenue Report 2012 Full Year Results April 2013, https://www.iab.com/wp-content/uploads/2015/05/IABInternetAdvertisingRevenueReportFY2012POSTED.pdf; PwC, "IAB Internet Advertising Revenue Report 2017 Full Year Results, May 2018, https://www.iab.com/wp-content/uploads/2018/05/IAB-2017-Full-Year-Internet-Advertising-Revenue-Report.REV2_.pdf; IAB, "The Definitive Guide to the European Digital Advertising Market," 2017, https://www.iabeurope.eu/wp-content/uploads/2018/06/IAB-Europe_AdEx-Benchmark-2017-Report_FINAL-V2.pdf.

153. HIS Technology, "Paving the Way: How Online Advertising Enables the Digital Economy of the Future," 18, https://www.iabeurope.eu/files/9614/4844/3542/IAB_IHS_Euro_Ad_Macro_FINALpdf.

154. Mike Butcher, "Stupid EU Cookie Law Will Hand the Advantage to the US, Kill Our Startups Stone Dead," TechCrunch, accessed May 28, 2014, http://techcrunch.com/2011/03/09/stupid-eu-cookie-law-will-hand-the-advantage-to-the-us-kill-our-startups-stone-dead/; Meg Leta Ambrose, "The Law and the Loop" (Proceedings of the International Symposium on Ethics in Engineering, Science, and Technology, 2014).

155. Daniel Castro and Alan McQuinn, "The Economic Costs of the European Union's Cookie Notification Policy" (Information Technology & Innovation Foundation, November 2014), http://www2.itif.org/2014-economic-costs-eu-cookie.pdf.

156. Teradata, "The State of Artificial Intelligence for Enterprises," Enterprises, http://assets.teradata.com/resourceCenter/downloads/AnalystReports/Teradata_Report_AI.pdf.

157. Ibid.

158. VVA. "Study for the Introduction of an E-labelling Scheme in Europe, June 2018, http://www.digitaleurope.org/DesktopModules/Bring2mind/DMX/Download.aspx?Command=Core_Download&EntryId=2695&language=en-US&PortalId=0&TabId=353.

159. Nigel Cory, "How E-Labels Can Support Trade and Innovation in ICT" (Information Technology and Innovation Foundation, 2017), http://www2.itif.org/2017-e-label-support-ict.pdf?_ga=2.137271088.1654604113.1532010331-1559993869.1449863882.

160. Van Reenen et al., "The Economic Impact of ICT, SMART."

161. Ibid, 14.

162. Ibid.

163. Cristiano Antonelli and Francesco Quatraro, "Localized Technological Change and Efficiency Wages across European Regional Labour Markets," *Regional Studies* 47, no. 10 (2013), 1686–1700.

164. Tillmann Schwörer, "Offshoring, Domestic Outsourcing and Productivity: Evidence for a Number of European Countries," *Review of World Economics* 149, no. 1 (2013), 131–49; Jerry Luftman et al., "Key Information Technology and Management Issues 2011–2012: An International Study," *Journal of Information Technology* 27, no. 3 (2012), 198–212; "Talking Points," *Information Services Group*, February 2013, http://www.isg-one.com/web/research-insights/talking-points/archive/1302.asp.

165. Alberto Francesco Alesina, Michele Battisti, Joseph Zeira, "Technology and Labor Regulations: Theory and Evidence," (working paper, Harvard University, 2014), https://dash.harvard.edu/handle/1/34330171.

166. Ibid.

167. Gilbert Cette, Jimmy Lopez, Jacques Mairesse, "Upstream Product Market Regulations, ICT, R&D and Productivity," *Income and Wealth,* February 2017, vol 63.

168. Wen Chen, Thomas Niebel, and Marianne Saam, "Are intangibles more productive in ICT-intensive industries? Evidence from EU countries," Telecommunications Policy 40, no. 5, (2016), 471–84.

169. Kevin Sneader et al., *From Austerity to Prosperity: Seven priorities for the long term* (McKinsey and Company, London / McKinsey Global Institute, November 2010), https://www.mckinsey.com/~/media/McKinsey/dotcom/Insights%20and%20pubs/MGI/Research/Productivity%20Competitiveness%20and%20Growth/From%20austerity%20to%20prosperity/MGI_UK_From_austerity_to_prosperity_full_report.ashx; Bill Lewis et al., *Removing Barriers to Growth and Employment in France and Germany* (McKinsey Global Institute, March 1997), http://www.mckinsey.com/insights/europe/removing_barriers_to_growth_and_employment_in_france_and_germany.

170. Paul C. Cheshire, Christian Hilber, and Loannis Kaplanis, "Land Use Regulation and Productivity-Land Matters: Evidence from a UK Supermarket Chain" (working paper, University Rovira i Virgili Department of Economics, 2012), http://www.recercat.net/handle/2072/196650.

171. Stephen J. Ezell, "Boosting Exports, Jobs, and Economic Growth by Expanding the ITA" (Information Technology and Innovation Foundation, March 2012), http://www.itif.org/publications/boosting-exports-jobs-and-economic-growth-expanding-ita.

172. UHY, “An International Comparison of Indirect Taxation: Exploring Government’s Contribution to the Cost of Everyday Goods” (UHY, December 2012), http://www.uhy.com/wp-content/uploads/UHY-Indirect-Taxes-Report-FINAL-DEC-2012.pdf.

173. Ibid.

174. OECD, *Consumption Tax Trends 2012* (OECD Publishing, 2012), http://www.oecd-ilibrary.org/taxation/consumption-tax-trends-2012_ctt-2012-en.

175. Greg Sterling, “France Wants To Tax Facebook, Google ‘Personal Data Collection,’” *Marketing Land*, January 21, 2013, http://marketingland.com/france-wants-to-tax-facebook-google-personal-data-collection-31196; Jacob Albert, “France Wants to Tax Data Mining, and It’s Not a Bad Idea,” *Quartz*, January 22, 2013, http://qz.com/45764/france-wants-to-tax-data-mining-and-its-not-a-bad-idea/.

176. For theoretical background on the incentives faced by corporations, see: Harry DeAngelo and Ronald W. Masulis, “Optimal Capital Structure Under Corporate and Personal Taxation,” *Journal of Financial Economics* 8, no. 1 (March 1980): 3–27, http://papers.ssrn.com/abstract=1482270; Robert M. Dammon and Lemma W. Senbet, “The Effect of Taxes and Depreciation on Corporate Investment and Financial Leverage,” *The Journal of Finance* 43, no. 2 (June 1988), 357, doi:10.2307/2328465.

177. Jane Gravelle, “Practical Reform for a More Efficient Income Tax,” *Virginia Tax Review* 30, no. 2 (2010).

178. Christoph Spengel, Christina Elschner, and Dieter Endres, *Effective Tax Levels at the Industry Level Using the Devereux/Griffith Methodology* (On-Demand Report, Mannheim: ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research, June 2012), http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.278.3739&rep=rep1&type=pdf.

179. “Taxation Trends in the European Union: Data for the EU Member States, Iceland and Norway,” Taxation and Customs Union, (Luxembourg: European Commission - Eurostat, 2013).

180. OECD, *Science Technology & Industry Scoreboard 2013* (OECD Publishing) http://www.oecd.org/sti/scoreboard.htm; Bart van Ark, Vivian Chen, and Kirsten Jäger, “European Productivity Growth Since 2000 and Future Prospects,” International Productivity Monitor 25 (2013), 65–83.

181. Bart van Ark et al., “European Productivity Growth.”

182. Bob Violino, “Productivity Gains: Quantity Plus Quality,” *Optimize Magazine* 28, February 2004, http://www.optimizemag.com/issue/028/execreport.htm.

183. Nicholas Bloom, Raffaella Sadun, and John van Reenen, “Americans Do IT Better: US Multinationals and the Productivity Miracle,” *American Economic Review* 102, no. 1 (February 2012): 167–201, doi:10.1257/aer.102.1.167.

184. Nick Bloom and John van Reenen, “Measuring and Explaining Management Practices Across Firms and Countries,” *The Quarterly Journal of Economics* 122, no. 4 (2007), 1351–1408.

185. Phil Fersht and Jamie Snowdon, “State of the Outsourcing Industry 2013: Executive Findings” (HfS Research, April 2013), http://www.kpmginstitutes.com/shared-services-outsourcing-institute/insights/2013/pdf/state-of-outsourcing-2013-exec-findings-hfs.pdf.

186. Fabiano Schivardi and Tom Schmitz, “The ICT Revolution and Southern Europe’s Two Lost Decades” (working paper, Social Science Research Network, 2018).

187. Davide Castellani et al, “The source of the US /EU Productivity Gap: Less and Less Effective R&D” (working paper, LEM Paper Series, Laboratory of Economics and Management, Sant’Anna School of Advanced Studies, Pisa, Italy, 2018).

188. Wen Chen, Thomas Niebel b, Marianne Saam, "Are intangibles more productive in ICT-intensive industries? Evidence from EU Countries Telecommunications Policy," 40, (2016), 471–484.

189. Reinhilde Veugelers, "Remaking Europe: The New Manufacturing as an Engine for Growth," 69, http://bruegel.org/wp-content/uploads/2017/09/Remaking_Europe_blueprint.pdf.

190. Dan Andrews, Giuseppe Nicoletti, and Christina Timiliotis, "Digital Technology Diffusion: a Matter of Capabilities, Incentives or Both?" (working paper, OECD Economics Department, Paris, 2018).

191. Fabiano Schivardi and Tom Schmitz, "The ICT Revolution and Southern Europe's Two Lost Decades" (working paper, Social Science Research Network, 2018).

192. "Flash Eurobarometer 369: Investing in Intangibles: Economic Assets and Innovation Drivers for Growth," EU Open Data Portal, accessed August 25, 2018, https://data.europa.eu/euodp/data/dataset/S1034_369.

193. Dan Andrews, Giuseppe Nicoletti, and Christina Timiliotis, "Digital Technology Diffusion: A Matter of Capabilities, Incentives or Both?" (working paper, OECD Economics Department, Paris, 2018).

194. Ibid.

195. OECD.Stat, Graduates by Field, https://stats.oecd.org/, accessed 12 September 2018.
World Bank, Total Labor Force, https://data.worldbank.org/indicator/sl.tlf.totl.in, accessed 13 September 2018.

196. OECD Data, "Entrepreneurship" (Employees by business size; accessed July 26, 2018), https://data.oecd.org/entrepreneur/employees-by-business-size.htm.

197. OECD, *Entrepreneurship at a Glance* (Table 2.2; Table 2.6 [percent]; accessed April 4, 2014), www.oecd-ilibrary.org/sites/entrepreneur_aag-2013-en/02/02/index.html.

198. Ibid.

199. Danny Leung, Césaire Meh, and Yaz Terajima, "Firm Size and Productivity" (working paper, Bank of Canada, 2008), http://www.econstor.eu/handle/10419/53956.

200. Countries not included are Denmark, Ireland, France, Sweden, Portugal, Romania, Hungary, Italy, Cyprus Eurostat. Structural Business Statistics (SMEs—annual enterprise statistics by size class), accessed March 7, 2016, http://ec.europa.eu/eurostat/web/structural-business-statistics/structural-businessstatistics/sme.

201. Labor Productivity by Size of Enterprise (2012). Source: Eurostat, Structural Business Statistics. Countries not included: Denmark, Ireland, France, Sweden, Portugal, Romania, Hungary, Italy, Cyprus

202. Lorin M. Hitt, D. J. Wu, and Xiaoge Zhou, "Investment in Enterprise Resource Planning: Business Impact and Productivity Measures," *J. of Management Information Systems* 19, no. 1 (2002): 71–98.

203. Fabiano Schivardi and Tom Schmitz, "The ICT Revolution and Southern Europe's Two Lost Decades" (working paper, Social Science Research Network, 2018).

204. Fabiani Schivardi, "ICT Adoption in Italian Manufacturing: Firm-Level Evidence," *Industrial and Corporate Change* 14, no. 2 (February 7, 2005): 225–249, doi:10.1093/icc/dth050.

205. Ibid; Nicholas Crafts, *Western Europe's Growth Prospects: An Historical Perspective*, CAGE Online Working Paper Series (Competitive Advantage in the Global Economy (CAGE), 2012), http://ideas.repec.org/p/cge/warwcg/70.html.

206. Luis Garicano, Claire Lelarge, and John van Reenen, *Firm Size Distortions and the Productivity Distribution: Evidence from France* (National Bureau of Economic Research, 2013), http://www.nber.org/papers/w18841.

207. European Commission Enterprise and Industry, *Putting Small Businesses First Europe is Good for SMEs, SMEs Are Good for Europe 2008 Edition,* http://ec.europa.eu/DocsRoom/documents/2278/attachments/1/translations/en/renditions/pdf.

208. Valeriano Martínez San Román, Marta Bengoa Calvo, and Blanca Sánchez-Robles Rute, "European Union and Trade Integration: Does the Home Bias Puzzle Matter?," *Revista de Economía Mundial*, no. 32 (2012).

209. Bart van Ark, "Recent Trends in Europe's Output and Productivity Growth Performance at the Sector Level, 2002-2015," *International Productivity Monitor,* 2017, vol. 33, p. 21.

210. Nicholas Crafts, "Making Europe Great Again?" CAGE, University of Warwick, (Preliminary version of paper presented to "Restoring Prosperity" Conference, Hoover Institution, Stanford University), 2017, https://www.hoover.org/sites/default/files/nicholas_crafts_making_europe_great_again.pdf.

211. Reinhilde Veugelers, "Remaking Europe: The New Manufacturing as an Engine for Growth," 188, http://bruegel.org/wp-content/uploads/2017/09/Remaking_Europe_blueprint.pdf.

212. OECD Key ICT Indicators, "10a. Share of ICT value added in the business sector value added," http://www.oecd.org/sti/broadband/oecdkeyictindicators.htm.

213. Ibid.

214. See for example the sectoral focus on this European Commission website: European Commission: Enterprise and Industry "ICT for Competitiveness & Innovation," (accessed May 16, 2014) http://ec.europa.eu/enterprise/sectors/ict/.

215. "A European strategy for Key Enabling Technologies - A bridge to growth and jobs" Communication adopted on 26 June 2012, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52012DC0341:EN:NOT.

216. Meghan Coyle, "French Term for American Tech Giants Reflects Resentment," *Etcentric*, December 4, 2014, http://www.etcentric.org/french-term-for-american-tech-giants-reflects-resentment/.

217. Nicholas Oulton, "Long Term Implications of the ICT Revolution: Applying the Lessons of Growth Theory and Growth Accounting," Economic Modelling 29, no. 5 (2012), 1722–1736.

218. Ibrahim Kholilul Rohman, "The Globalization and Stagnation of the ICT Sectors in European Countries: An Input-Output Analysis," *Telecommunications Policy* 37, no. 4–5 (May 2013): 387–399, doi:10.1016/j.telpol.2012.05.001.

219. David Bryne and Carol Corrado, "ICT Prices and ICT Services: What Do They Tell Us About Productivity and Technology?," (Finance and Economics Discussion Series 2017-015, Federal Reserve, Washington, 2017), https://www.federalreserve.gov/econresdata/feds/2017/files/2017015pap.pdf.

220. European Commission, *A Digital Single Market Strategy for Europe,* (Brussels: Communication from the Commission, May 2015), https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52015DC0192.

221. Raquel Ortega-Argilés, "The Transatlantic Productivity Gap: A Survey of the Main Causes," *Journal of Economic Surveys* 26, no. 3 (July 2012): 395–419, doi:10.1111/j.1467-6419.2012.00725.x, 403.

222. Peter Gumbel, "France Loves Tech, but Not Amazon, or Uber, or Google, or ...," *Bloomberg View*, February 12, 2014, http://www.bloombergview.com/articles/2014-02-12/france-loves-tech-but-not-amazon-or-uber-or-google-or-.

223. Robert Atkinson, "Don't Fear AI," *European Investment Bank,* June 15, 2018, http://www.eib.org/essays/artificial-intelligence?mc_cid=8dec0cd27b&mc_eid=0ac4593ac6.

224. Three percent growth per year leads to a doubling in 27 years.

225. Bert Colijn, "Green Jobs in Europe and the Increasing Demand for Technical Skills" (The Conference Board Europe, February 2014), http://www.neujobs.eu/publications/working-papers/green-jobs-europe-and-increasing-demand-technical-skills.

226. Miller and Atkinson, "Are Robots Taking Our Jobs, or Making Them?," 17–20.

227. "Current Members," The European Productivity Network (EANPC), accessed July 25, 2018, http://www.eanpc.eu/en/members/current-members/.

228. To see why, consider a country in which average productivity among existing firms increases 2 percent per year for five years. After 5 years, national productivity is up by almost 11 percent. To achieve a similar increase in total productivity through an industry mix strategy, a country would have to replace 20 percent of its jobs with average value-added per worker with jobs having a value-added of over 50 percent more, an unlikely transformation at best. James Manyika et al., *How to Compete and Grow: A Sector Guide to Policy* (McKinsey Global Institute, March 2010), http://www.mckinsey.com/insights/economic_studies/how_to_compete_and_grow.

229. See for example: Rob Frieden, "Lessons from Broadband Development in Canada, Japan, Korea and the United States," *Telecommunications Policy* 29, no. 8 (September 2005), 595–613, doi:10.1016/j.telpol.2005.06.002.

230. Robert D. Atkinson and Daniel Castro, "Digital Quality of Life: Understanding the Benefits of the IT Revolution" (Information Technology & Innovation Foundation, October, 2008), http://www.itif.org/publications/digital-quality-life-understanding-benefits-it-revolution.

231. Bradford DeLong and Lawrence Summers, "Equipment Investment and Economic Growth: How Strong is the Nexus?," *Brookings Papers on Economic Activity* 23 (1992); Jonathan Temple and Hans-Joachim Voth, "Human capital, equipment investment, and industrialization," *European Economic Review* 42, no. 7 (1998): 1343–62; Bart van Ark, "Measuring the New Economy, An International Comparative Perspective," *Review of Income and Wealth* 48 (2002), 1–14; Hitt and Tambe, "Measuring Spillovers from Information Technology Investments," 1793; Xavier Sala-i-Martin, "15 Years of New Growth Economics: What Have We Learnt?" (keynote address to the fifth annual conference of the Central Bank of Chile The Challenges of Economic Growth, Santiago, Chile, November 29-30, 2001).

232. "Contribution to the Annual Growth Survey 2014: A Single Market for Growth and Jobs: An Analysis of Progress Made and Remaining Obstacles in the Member States" (report from the Commission to the European Parliament, the Council, the European Central Bank, the European Economic and Social Committee, the Committee of Regions and the European Investment Bank, November 2013), http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013DC0785.

233. Daniel Castro and Alan McQuinn, "Cross-Border Data Flows Enable Growth in All Industries" (Information Technology and Innovation Foundation, February 2015), https://itif.org/publications/2015/02/24/cross-border-data-flows-enable-growth-all-industries.

234. Robert D. Atkinson, "Don't Just Fix Safe Harbour, Fix the Data Protection Regulation," *EURACTIV,* December 18, 2015, https://www.euractiv.com/section/digital/opinion/don-t-just-fix-safe-harbour-fix-the-data-protection-regulation/.

235. See for example: "Small companies create 85% of new jobs," Enterprise and Industry, European Commission website, last modified January 16, 2012, accessed April 18, 2014, http://ec.europa.eu/enterprise/newsroom/cf/itemdetail.cfm?item_id=5708.

236. Robert D. Atkinson, "In Praise of Big Business: Part 1," *Innovation Files,* June 22, 2012, http://www.innovationfiles.org/in-praise-of-big-business-part-1/.

237. Albert Bravo-Biosca et al., "What Drives the Dynamics of Business Growth?," *OECD Science, Technology and Industry Policy Papers*, no. 1 (April 4, 2013), http://www.oecd-ilibrary.org/science-and-technology/what-drives-the-dynamics-of-business-growth_5k486qtttq46-en.

238. "Small Is Not Beautiful," *The Economist*, March 3, 2012, http://www.economist.com/node/21548945.

239. Murat Seker, "Rigidities in Employment Protection and Exporting," *World Development* 40, no. 2 (2012), 238–50.

240. "France - French Lawmakers on Both Sides Unite to Spear Amazon," France 24, accessed May 23, 2014, http://www.france24.com/en/20131003-national-assembly-amazon-book-law-free-shipping-competition-ump-socialist-lang/.

241. Nigel Cory, "Cross-Border Data Flows: Where Are the Barriers, and What Do The Cost?" (Information Technology and Innovation Foundation, May 2017), https://itif.org/publications/2017/05/01/cross-border-data-flows-where-are-barriers-and-what-do-they-cost.

242. Ibid.

243. For example, Catherine Tucker has found that the EU privacy directive lowered online advertising effectiveness by 65 percent relative to the rest of the world. Catherine Tucker, "Economics of Privacy" (MIT Sloan and NBER, November 15, 2012), http://www.ftc.gov/sites/default/files/documents/public_events/fifth-annual-microeconomics-conference/tucker.pdf.

244. Daniel Castro, Nick Wallace, "The Impact of the EU's New Data Protection Regulation on AI" (Center for Data Innovation, March 2018), http://www2.datainnovation.org/2018-impact-gdpr-ai.pdf.

245. Nick Wallace, "EU E-Privacy Proposal Risks Breaking 'Internet of Things,'" *EUobserver,* March 13, 2018, https://euobserver.com/digital/141302.

246. Nick Wallace, "Policymakers Must Be Careful On 'Platform Regulation,'" *EUobserver,* April 30, 2018, https://euobserver.com/science/141714.

247. Doug Brake, "Letter to the Body of European Regulators for Electronic Communications (BEREC) Regarding Net Neutrality Guidelines," (Information Technology and Innovation Foundation, April 2018), https://itif.org/publications/2018/04/25/letter-body-european-regulators-electronic-communications-berec-regarding.

248. Doug Brake, "Spectrum Policy and the EU Digital Single Market: Lessons from the United States" (Information Technology and Innovation Foundation, December 2015), https://itif.org/publications/2015/12/07/spectrum-policy-and-eu-digital-single-market-lessons-united-states.

249. Mark Scott, "Uber Faces Rebukes in Europe," *New York Times*, accessed April 18, 2014, http://bits.blogs.nytimes.com/2014/04/17/uber-faces-rebukes-in-europe/.

ACKNOWLEDGMENTS

The author wishes to thank John Wu and Caleb Foote for research assistance and MacKenzie Wardwell for editorial assistance. Any errors or omissions are the author's alone.

ABOUT THE AUTHOR

Robert D. Atkinson is the founder and president of ITIF. Atkinson's books include *Big is Beautiful: Debunking the Myth of Small Business* (MIT, 2018), *Innovation Economics: The Race for Global Advantage* (Yale, 2012), and *The Past and Future of America's Economy: Long Waves of Innovation That Power Cycles of Growth* (Edward Elgar, 2005). Atkinson holds a Ph.D. in city and regional planning from the University of North Carolina, Chapel Hill, and a master's degree in urban and regional planning from the University of Oregon.

ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized as the world's leading science and technology think tank, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

FOR MORE INFORMATION, VISIT US AT WWW.ITIF.ORG.