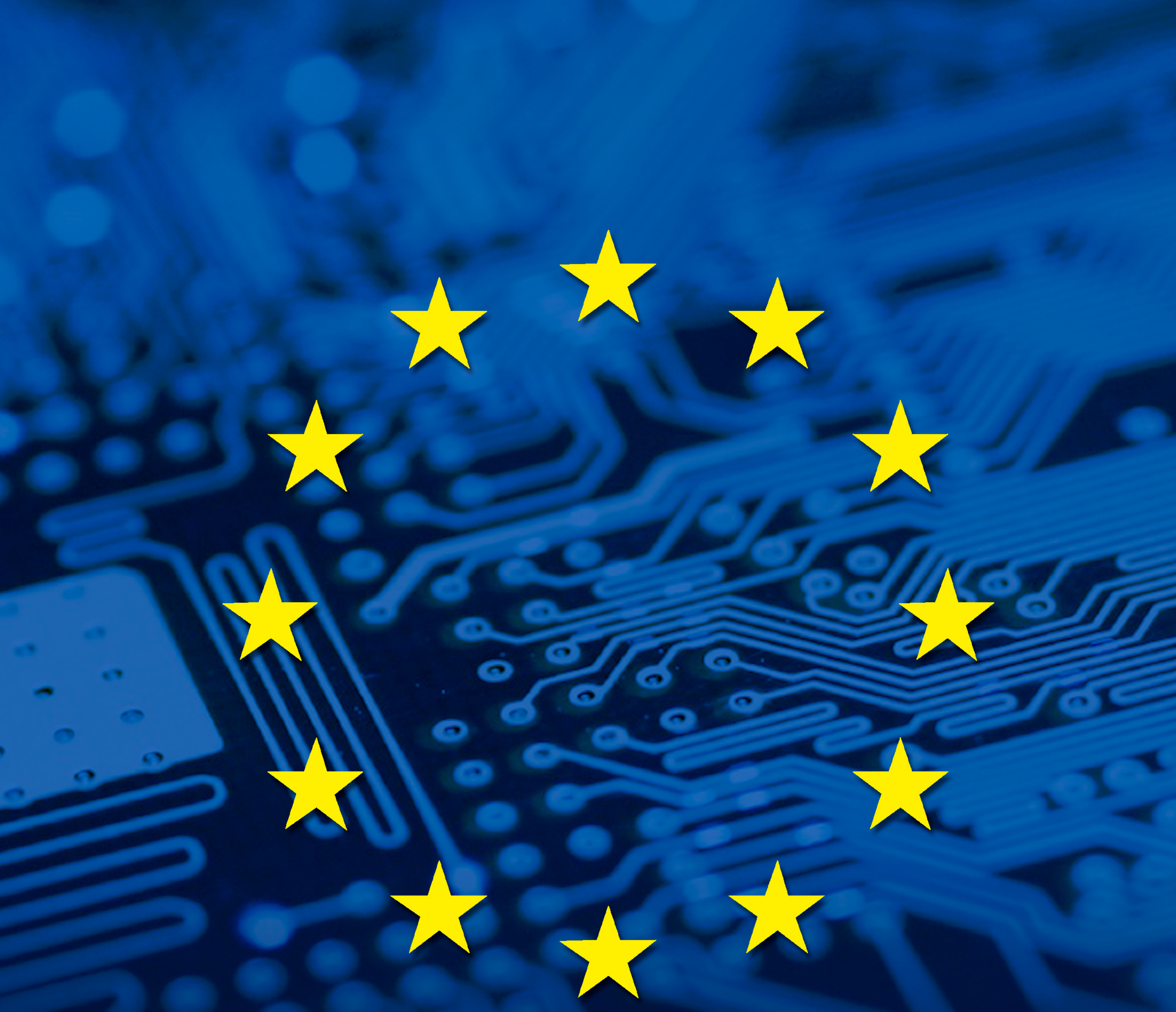

PROMOTING EUROPEAN GROWTH, PRODUCTIVITY, AND COMPETITIVENESS BY TAKING ADVANTAGE OF THE NEXT DIGITAL TECHNOLOGY WAVE

ITIF
INFORMATION TECHNOLOGY & INNOVATION FOUNDATION

ITIF.ORG

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PREFACE

In the second half of 2019, Finland will assume the presidency of the European Council. One key issue for the Finnish government as it occupies that role will be how to better position Europe for the next phase of the digital economy. To help better understand this, the Finnish government (Ministry of Economic Affairs and Employment) has asked the Information Technology and Innovation Foundation (ITIF) to provide an analysis and recommendations for how Europe can best achieve digital success, as seen from a non-EU perspective.

ABOUT ITIF

The Information Technology and Innovation Foundation 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 policy think tank, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

DISCLAIMER

The ideas and proposals herein represent the views of ITIF and not those of the Finnish government or the upcoming Finnish EU presidency.

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EXECUTIVE SUMMARY

A new suite of digital technologies is reshaping advanced economies and promising increased rates of innovation, productivity, and economic growth, along with improvements in quality of life. However, the EU will not gain the full benefits of this next innovation wave without the right policies.

This report begins by discussing the emerging digital technology transformation, what is required for success, and where Europe stands vis-à-vis progress on digital development and adoption. It then compares Europe with China, Japan, and the United States in terms of indicators of both digital economy development and adoption as well as key policies and factors related to digital economy success. It then lays out six key strategic issues for the EU as it seeks competitive advantage and growth from the next technology wave. Finally, the report presents a series of policy recommendations for the EU, organized into five sections: regulatory framework conditions, trade policy, resources for firms (including data, R&D, skills and digital infrastructure), technology/sector/firm policies, and culture and institutions.

The Task Ahead: Transforming Europe Through Connectivity, Automation, and Smart Systems (CAS)

Europe faces a set of important new challenges and opportunities as the next wave of ICT-based innovations emerges. Advanced nations and regions are in the beginning stages of a major technology wave; a transformation to a more sophisticated, powerful, and wide-ranging digital system. This system will be much more connected (a massive number of "things" will be connected through more advanced networks), automated (devices and systems will enable more work to be done by "machines"), and smart (algorithms will play important roles in making sense of and acting on all this information). As a shorthand, we call this system connected, automated, and smart (CAS).

Successful development and adoption in the EU will likely lead to significant benefits, not the least of which includes the potential return to the kinds of robust rates of productivity growth EU nations enjoyed from 1980 to 1995. Indeed, this next innovation wave holds the potential to reverse the 20-year productivity growth lag suffered by the EU. Moreover, CAS adoption will help address pressing EU challenges, including in the areas of education, environment, health, and transportation. And CAS development could boost EU global competitiveness.

Because of the nature of this next wave, especially its potential transformation of "atom-based" industries, the EU is better positioned to succeed than it was in the last ICT wave, as Europe has many strengths it can leverage for success, including strong research universities, a highly skilled workforce, a large market, world-leading firms, and. importantly, core engineering strengths and a willingness to engage in public-private digital transformation projects. However, the EU also faces challenges, including lower ICT industry investment in R&D than in the United States and Japan, lower rates of ICT patenting, lower levels of entrepreneurial risk taking and a weaker ecosystem (e.g., venture capital) that accompanies it. The EU also has a much larger share of small firms than the United States, which limits innovation, investment, and productivity. Firms in the EU also invest less in ICT and spend less on digital services (including cloud computing and other information services).

Key Strategic Issues for the EU

As the EU considers how it wants to fully support and capitalize on the innovations emerging from the coming CAS transformation, it needs to consider several strategic factors.

1. Focus on the Future, Not the Past

The EU missed many of the opportunities from the last two ICT waves, including in personal computers, smartphones, cloud computing, Internet search, and social media. Because of the enormous economies of scale and scope, and first-mover advantages global leading firms have in these areas, it will be extremely difficult for the EU to break into these industries in a serious way. This implies the EU should focus on the industries and technologies of the future, and not on gaining market share in the current wave of ICT industries. The business and national winners in the CAS system (e.g., robotics, autonomous systems, blockchain, quantum computing, artificial intelligence, 5G, Internet of Things, etc.) are not preordained, and any current competitive advantage by no means assures future advantage. As such, the EU should focus on winning global market share in the emerging CAS technology areas.

The EU should focus on the industries and technologies of the future, not the recent past, and build on existing core competencies.

2. Focus on Areas of Competitive Advantage

The EU also needs to focus on areas of existing competitive advantage. Previous digital technology waves were largely about "bits"; in other words, purely digital technologies. The next wave will be increasingly about "bits and atoms," or, the emerging technology system increasingly combining digital technologies with physical things and activities (e.g., smart agriculture, smart cities, smart grids, smart manufacturing, autonomous vehicles, etc.). This plays well to the EU's considerable strengths in engineering, provided, however, the EU improves and expands its software capabilities. However, this means conceiving of "Industry 4.0" broadly, and not just on manufacturing. The digital transformation of "atom-based" industries is much broader than just manufacturing. All physical systems, including agriculture, buildings, infrastructure, logistics, and transportation, are being digitized—all areas wherein the EU has real strengths.

Another area of strength for the EU is technology-enabled business services, including in accounting and finance, engineering services, supply chain and logistics, environmental compliance, consulting, graphics design, and biometrics. Moreover, this is an area wherein East Asian capabilities are much less developed. The EU can build on both its own and national government policy efforts in areas such as health IT and genetic records, e-government services, digital IDs, fintech, blockchain-enabled logistics, and others. In particular, global liberalization of the services trade provides a core opportunity for Europe, especially as more services are being digitized and able to be more easily traded across borders, and the free flow of data across borders is enabled.

3. Address Unequal Adoption of Digital Tools Between Firms, Industries, and Nations

If the EU is to fully succeed in the CAS era, it needs to successfully address three key gaps. The first is too many EU organizations lag in their adoption of past and current waves of ICT. There is a considerable gap between leading firms and "zombie firms" (firms with low productivity growth and limited ICT adoption). And the EU has a significantly larger share of employment in small, relatively low-productivity, low-ICT-using firms protected by public policies that provide incentives to not get big, as getting big brings with it a host of regulatory and tax obligations.[1]

Second, the gaps are not just between firms, but industries. ICT adoption is less even between European industries than it is in the United States. This is a major reason the gap between the most-productive and least-productive firms in any particular EU industry is higher than in the United States.

The third gap is between nations. Some EU nations, such as the Nordic nations, are on par with, 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 in ICT development and adoption.

4. Shift the Strategic Focus of the EU's Digital Policies

There are three principal types of digital economy policies: foundational, field clearing, and proactive. Foundational policy activities are focused on addressing potential harms from ICT or ICT companies. Field-clearing policies are focused on clearing barriers and limiting future barriers to digital innovation. Proactive policies seek not just to open markets and enable digital entrants to compete, but to actively support EU-wide digital transformation. While EU member states and the European Union have taken steps in all three areas, much of the focus has been on foundational policies, and relatively less on field-clearing and proactive policies.

Yet, proactive digital policies represent the next big opportunity for EU digital policy. These include policies to expand and improve the resources firms rely on for success, including ICT R&D, data, broadband networks, and digital skills. The latter is particularly important, as Europe lags behind the United States in the share of the workforce with software skills, which is arguably the key ingredient for digital economy success. But proactive policies, often implemented through public-private partnerships, also support digital innovation and adoption in key technology areas, such as AI, digital IDs, high-performance computing, and robotics, and key application areas such as health IT, smart grids, and smart cities.

5. Build on the EU's Unique Advantages

While the EU lags behind the United States and China in several areas related to the digital economy, it has several unique advantages, particularly over the United States. To win in the next CAS wave, the EU needs to double down on these advantages. There are two that deserve particular focus. First, compared with the United States, the EU is much more open to supporting proactive policies to help drive digital transformation in particular areas, such as the smart grid, smart cities, health IT, E-IDs, etc. Taking advantage of this can not only produce needed transformation, but also give EU firms a leg up in global competition.

Second, the EU can take advantage of policy innovation going on in all EU nations, particularly in many of the smaller nations. National digital advantage in many technology and application areas depends both on coordination of multiple actors (a task that can be extremely difficult in large nations such as the United States) and policy innovation. But the EU has numerous nations that have shown a willingness and ability to be more innovative and flexible. The Commission should take advantage of these innovations, seeking to spur more bottom-up policy innovation and then bring those innovations fully to market, diffusing them throughout all of the EU. As such, a key challenge for the EU going forward will be to identify its many strengths and build on them while at the same time identifying weaknesses and taking steps to overcome them.

6. Win Through Out-Investing the United States

One reason for America's lead in the last two ICT waves is significant public investment from the 1960s to the 1980s, especially in R&D, including through the Department of Defense, NASA, and the National Science Foundation. But years of budget neglect have resulted in the United States now ranking eighth among Organization for Economic Cooperation and Development (OECD) nations in the ratio of government-funded R&D to GDP. And current budget challenges in the United States suggest this will only get worse. This provides the EU with a real opportunity to gain ground on the United States through more robust public investment, particularly in R&D focused on CAS technologies. However, the EU will also need more effective technology transfer and commercialization —an area in which the United States does quite well—if it is to get the most out of increased investments in R&D.

Policy Recommendations

The report makes a number of recommendations in five main areas: regulation, trade policy, resources for firms (including data, R&D, skills and digital infrastructure), technology/sector/firm policies, and culture and institutions. **These are not intended to be set in stone, but rather as suggestions of the kinds of steps the EU may want to consider.**

Regulatory Framework Conditions

- In efforts to "level the playing field" between industries and firms, the EU should be focused more on equivalent protection, not equivalent regulation. In other words, the goal should not be to subject new digitally-based business models to the same regulation as incumbents—which often limits innovation.

- The Commission should actively support national efforts to reform and improve regulation. In particular, this will mean a greater embrace of the "innovation principle" when considering government response to new technologies.
- In order to enable digital single market, the Commission should be given political-level support to preempt digital economy regulations individual member states adopt.
- The Commission should create within the Regulatory Scrutiny Board an Office of Innovation Review whose mission would be to serve as an "innovation advocate" in the regulatory process.
- The Commission and member states should continue developing "regulatory sandboxes"—frameworks that enable firms to work with regulators to test their innovative products, services, and business models with real consumers in a controlled environment on a trial basis.

Trade Policy

- The Commission should be given the authority to review and approve or reject acquisitions of EU firms from nations practicing state capitalism.
- The EU should—within the text of its trade agreements, not outside of them—develop provisions to protect the role data flows play in digital trade in order to ensure other nations do not use privacy as a cover for digital protectionism, as it would make these measures subject to a trade dispute.
- The EU's digital trade agreement provisions should emphasize that firms will be held accountable for ensuring a country's data protection rules flow with the data.
- To better establish an EU single market for services, the EU needs to develop a more robust process to identify barriers to entry and operation in service markets, and reporting and transparency mechanisms to publicize relevant rules and regulations alongside a parallel effort to ensure regulatory agencies have the capability to enforce relevant rules and laws.
- The EU should take a leading role in reviving negotiations over an ambitious Trade in Services Agreement within the World Trade Organization.

Resources for Firms: Data, Research, Skills, and Infrastructure

- Every EU member state should appoint a chief digital officer to not only champion data innovation domestically, but also to serve on an EU-wide advisory panel charged with counseling the European Commission on development of a cohesive vision and strategy for capturing the full benefits of data-driven innovation.
- The Commission should adopt an ICT R&D funding system that gives EU industry much more say in determining the technology areas the EU funds. In contrast, for individual academic researchers and academic research centers, the Commission should identify areas of importance for ICT research and devote funds to projects in these areas.

- The Commission should reduce its role as a direct funder of large numbers of individual research projects and instead fund many more industry-funded university R&D centers on multiyear contracts.
- The Commission should establish an ICT-based Industry-University Cooperative Research Center program, wherein the research areas are determined by universities and industry working collaboratively.
- The Commission should establish a program to make awards of €1 million per year for 5 years to the top 100 or so individual academic researchers doing work in advanced ICT areas, such as AI, that industry values. This will help the best academic talent not only stay and develop in Europe, but also stay in academia rather than being lured to industry.
- The current proposal for the Directorate General for Research and Innovation for funding for R&D in robotics and artificial intelligence should be supported.
- The Commission should provide matching grants to member states to establish teacher-certification programs in computer science (CS) as the EU lags behind the United States in the production and employment of CS workers.
- The EU should build on public-private partnerships for computer science education and digital skills development. Many leading companies making or using digital technologies would likely be active participants in such programs.
- The Commission should fund a pilot program that would establish more maker spaces in European high schools, in order to boost digital manufacturing and engineering skills.
- The EU should consider the U.S. experience in creating a continent-wide telecom service market, including in spectrum, and assess its applicability in the EU.
- Wherever there are at least two competing broadband providers (e.g., wireline telecommunications, cable providers, or 5G wireless) in a market, the Commission should allow national governments to remove price regulations and wholesale network unbundling requirements.
- The EU should lower costs of deployment for 5G infrastructure by encouraging local authorities to streamline their infrastructure siting requirements.
- EU policymakers should continue to evaluate the benefits of differentiated network services, and whether existing net neutrality regulations impede innovative new broadband network applications.

Technology/Sector/Firm Policies

- The Commission should chart out steps articulating how it can help member states drive CAS applications through public-private partnerships. This should include heading an effort to help member states become lead adopters of emerging CAS technologies.

- The EU should focus on using existing programs and policies that affect particular industries to drive CAS transformation (e.g., agriculture and DG AGRI; financial and DG ECFIN; transportation and DG MOVE; etc.).
- Each major Directorate General should establish a position of chief technology officer to ensure Directorates' policies are aligned with CAS sector transformation.
- The EU should fund the establishment of an EU-wide version of America's Digital Manufacturing and Design Innovation Institute.
- The EU should fund a network of "manufacturing universities" focused on skills and R&D relevant to manufacturers in the EU.
- The EU should develop an "EU Smart City App Store"—a common repository of approved commercial applications and open-source code—other EU cities can adapt and reuse.
- The Commission should establish competitive programs to support member states that establish innovative CAS-related projects and initiatives.

Culture and Institutions

- The Commission should lead a dialogue that explores adopting the innovation principle, rather than the precautionary principle, when it comes to CAS.
- The EU should expand support for EU universities and colleges to create entrepreneurship education programs.
- The EU should provide challenge grants to universities to reform university engineering curricula toward more project-based learning and entrepreneurship.
- The EU should support innovative new organizational models in areas such as health care, transportation, and education.
- The EU should establish an EU-wide productivity agency to identify specific policies to spur faster technology-based productivity, and to act as a champion of stronger productivity policies. While the Commission encourages the establishment of National Productivity Boards, many key issues can only be addressed at the EU level.[2] Moreover, many of the national productivity boards focus on macroeconomic and regulatory framework issues, rather than the more critical industry-, technology-, and firm-specific issues related to productivity and policy.[3]

The EU has a significant opportunity to make major strides in the next wave of digital transformation, but it will need to adopt a forward-looking policy perspective that focuses foremost on the benefits the next generation of digital technologies can bring to Europe's economy and society. In particular, Europe should leverage its distinct strengths in areas such as collaborative public-private partnerships and advanced industrial engineering to position itself to be a global leader in the coming CAS transformation. While the EU should be attuned to potential digital harms, it should also remember that, in total, these are well-outweighed by digital benefits, and manage its digital policymaking framework accordingly.

INTRODUCTION: HOW ECONOMIES TRANSFORM THROUGH WAVES OF INNOVATION

The conventional economics view of innovation, to the extent economists have one, is that innovation is linear in nature—something that just proceeds regularly. In this view, innovation is, as economist Robert Solow wrote, "Manna from heaven."[4] But in fact, technological innovation appears to follow a pattern of repeating "S curves" with waves of technology emerging, developing, and then stagnating before the next new wave. This is what Joseph Schumpeter argued when he wrote that, "each of the long waves in economic activity consists of an 'industrial revolution' and the absorption of its effects."[5] The idea is that innovation progresses in regular cycles or waves approximately half a century long, with initial modest growth followed by a period of robust adoption and growth followed by stagnation.[6] As Schumpeter wrote:

> 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.[7]

Technological innovation appears to follow a pattern of repeating "S curves," with waves of technology emerging and then stagnating before the next new wave.

The key to Schumpeter's analysis is the insight that innovation is not a continuous process bringing steady incremental improvements but rather a discontinuous process that leads to waves of technological innovations. He also noted:

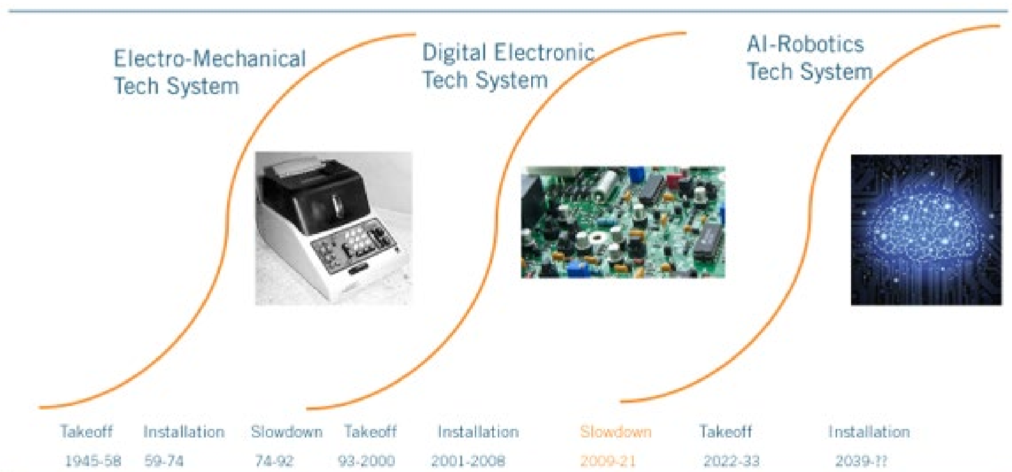
> These revolutions are not strictly incessant; they occurred in discrete rushes which are separated from each other by spans of comparative quiet. The process as a whole works incessantly, however, in the sense that there is always either revolution or absorption of the results of revolution, both together forming what are known as business cycles.[8]

This process of technological change has two critical characteristics that make it an important determinant of economic and social change. First, these long waves are not a large collection of incremental improvements in the existing technology system that emerge at the same time. Rather, they are waves of radical innovations that disrupt the current technology and production system. For example, the steam engine and the automatic spinning and weaving mill were not improvements on existing technology, but fundamentally new ones that reshaped British—and later continental European and American—economies in the first half of the 19th century. Likewise, while the microchip performed the same function as a vacuum tube, it was a radical and disruptive technology.

Second, these disruptive technologies do not just emerge one or two at a time, but rather burst onto the scene as an entire array that forms a mutually reinforcing technology system. The emergence of cheap steel in the 1880s and 1890s transformed not just the steel industry but also almost all of manufacturing, as a wide array of industries could then take advantage of low-cost, high-strength steel. These new technology systems periodically emerge and sweep through and transform the entire economic order. This is not to say innovation ceases after these revolutionary new technology systems emerge. Rather, it takes on a more incremental character, reinforcing and gradually improving, rather than disrupting, the newly formed technology system.

According to this periodization, there have been five waves to date: the steam engine, beginning in the 1780s and 1790s; iron, beginning in the 1840s and 1850s; steel and electricity, beginning in the 1890s and 1900s; electromechanical and chemical technologies, beginning in the 1950s and 1960s; and information and communications technologies, beginning in the 1980s and 1990s (see figure 1).[9]

Figure 1: Technology Long-Wave Periodization



This periodization points to several important conclusions. First, despite all the discussion about the world being in the midst of a Fourth Industrial Revolution, one can make a reasonably strong argument that we are closer to the end than the middle of the current digital technology S curve. This is true for two reasons. First, with regard to the existing information and communications technology (ICT) innovations, most are significantly less transformative than those of a decade or two ago. Take broadband telecommunications. Moving from a 56K 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 did users have an always-on system, broadband supported a wholly different set of applications than did the old ones, including voice and video. Going from 2 MB to 12 MB was still valuable, but it represented only a sixfold increase in speed. And while it enabled the emergence of video streaming and cloud computing, much of the rest of Internet applications (e.g., search, e-commerce, etc.) were improved, but not enabled. Likewise, going from 12 MB to 100 MB or even a gigabit per second is not a game changer, as some existing applications will work slightly better. It is possible that new applications that require super-fast speeds, such as holographic communications, could be developed. But so far, they are not here. We can see similar dynamics in operating systems wherein the shift from DOS to Windows was a major improvement, but the regular improvement in operating systems now, while helpful, are 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 providing a major increase in performance, is less important, at least to the average personal computer user's experience. Today, many people talk about the emergence of cloud computing as a similar revolution for 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.[10]

One recurring factor with shifts in long waves is that each has come with a shifting geographic center of gravity.

Second, the emerging applications many point to today—artificial intelligence (AI), autonomous vehicles (AVs), drones, flexible robots, etc.—are still relatively nascent and generally are too expensive and not effective enough to drive economy-wide productivity. For example, despite the excitement over "Industry 4.0" and Internet of Things technologies, most manufacturers appear to be in the very early stages of adopting these systems. A 2017 Sikich study found that 77 percent of U.S. small to medium-sized manufacturers still have no plans to implement Industrial Internet of Things solutions within the next three years.[11] Likewise, while there is considerable excitement about machine learning software systems, their current capabilities remain relatively limited, notwithstanding promising early applications. Fully autonomous cars at a price point most consumers can afford are likely at least 15 years away.[12] And fully dexterous robotic hands are not likely to be in the market before 2030, or even 2040.[13] As Rodney Brooks wrote, "Having ideas is easy. Turning them into reality is hard. Turning them into being deployed at scale is even harder."[14]

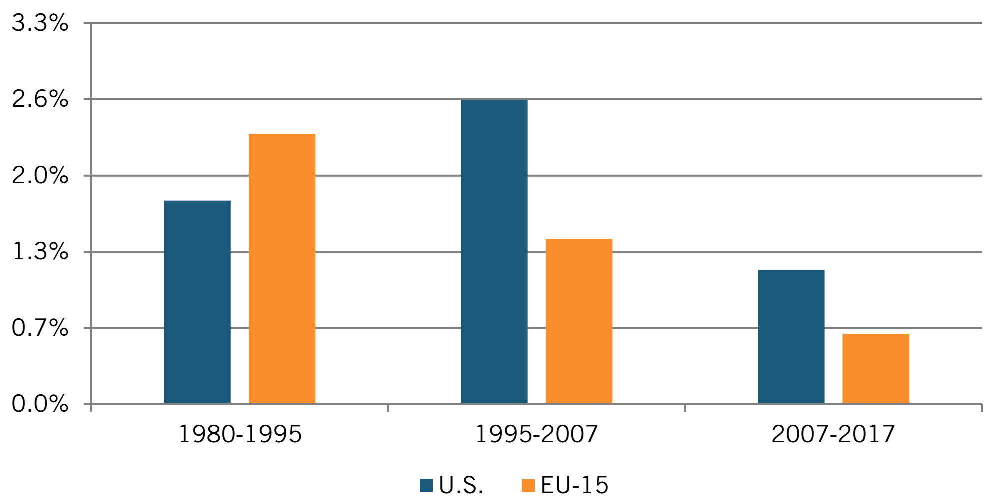
If this periodization is correct, it suggests that the current period of incremental innovation and relative productivity stagnation will eventually be replaced with a sixth technology wave grounded in new technologies that will be so powerful that organizations and people will be compelled to buy them en masse. Several technologies look like candidates to comprise the next innovation wave, including Internet of Things, 5G wireless systems, advanced robotics, blockchain, autonomous machines, and, perhaps the most important, AI.[15] AI has many functions, including but not limited to learning, understanding, reasoning, and interaction.[16] There are two very distinct types of AI: narrow and strong. Narrow AI describes computer systems adept at performing specific tasks, such as Apple's Siri virtual assistant, which interprets voice commands.[17] Strong AI, also referred to as artificial general intelligence (AGI), is a hypothetical type of AI that can meet or exceed human-level intelligence and apply its problem-solving ability to any type of problem.[18]

Many of the fears about AI, such as it leading to the elimination of most jobs, stem from the notion AGI is feasible and imminent.[19] However, for the foreseeable future, computer systems that can fully mimic the human brain are only going to be found in Hollywood scripts— not labs in Silicon Valley.

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 provide 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.[20]

This is particularly important for the EU as, compared with the United States, it has suffered from lagging productivity growth since 1995. U.S. labor productivity growth averaged 1.7 percent per year from 1980 to 1995, rose to 2.6 percent per year from 1995 through 2007, and then slowed to 1.1 percent yearly growth between 2007 and 2017.[21] 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 (see figure 2).[22]

Figure 2: EU-15 and U.S. Average Annual Labor Productivity Growth, 1980–2017[23]

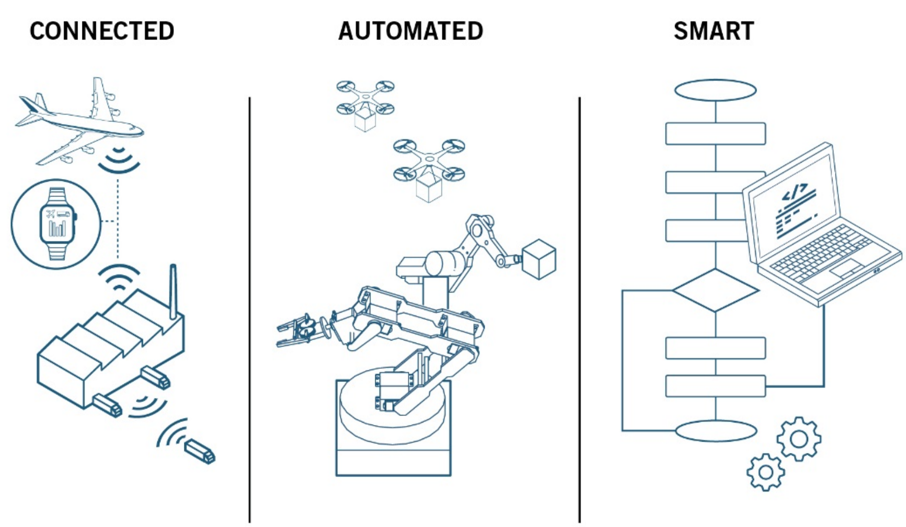


These lower rates have big implications. If the EU-15 nations had maintained the productivity growth rate they enjoyed from 1980 to 1995 through to 2017, their real GDP would be 31 percent larger today.[24] If EU labor productivity were to grow over the next 25 years at its 1980–1995 average of 2.3 percent 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 will grow by only 15 percent—not even enough to cover increased retirement costs from the greater share of retirees.[25]

THE TASK AHEAD: TRANSFORMING EUROPE THROUGH CONNECTIVITY, AUTOMATION, AND SMART SYSTEMS (CAS)

One recurring factor, with shifts in long waves, is that each has shifted the geographic center of economic activity. Britain led the first and second waves, Germany and the United States led the third, and the United States led the fourth (with Germany and Japan being robust competitors). The United States also leads the current fifth wave, largely as leading American companies effectively embraced first the Wintel system (Windows and Intel), wherein companies specialize in particular components, and later the Internet system, wherein leading companies gained global market share by relying on economies of scale and network economics. Moreover, between the fourth and fifth waves, the center of gravity shifted in the United States, with the former largely centered on the East Coast and the Midwest industrial heartland, and the fifth centered on the West Coast and a few East Coast pockets (e.g., Boston's Route 128). In 1974, Montoro Yuasa wrote about this phenomena, arguing that the geographic center of scientific and engineering creativity shifts over time.[26] If this is true, it suggests that the emergence of new technology systems represent inflexion points that not only raise risks to leading regions, but also enable regions that had not led in the earlier era to gain leadership in the new era. Clearly, China appears poised, or is at least seeking, to gain leadership in the next technology era. But this framing suggests that there is an opening for Europe to regain a leadership position.

Figure 3: The Emerging Connected, Automated, and Smart (CAS) Technology System



The current fifth technology wave is grounded in information and communications technology. It has evolved to include computing devices (computers, cell phones, servers, etc.) connected to the cloud, with many functions operating on platforms for search, e-commerce, and social media. However, advanced nations and regions are in the beginning stages of a next major technology wave; a transformation to a more sophisticated, powerful, and wide-ranging digital system. This system will be much more **connected** (a massive number of "things" will be connected, many by advanced wireless networks); **automated** (devices and systems will enable more work to be done by machines); and **smart** (algorithms, some of which have been developed by machine learning, will play important roles in making sense of and acting on all this information, including in helping to power machines). As a shorthand, we call this system **CAS**: connected, automated, and smart, as depicted in figure 3.

The challenge for any advanced nation or region is to be able to ensure a reasonable level of global competitiveness in CAS-based industries wherein firms are developing the technology and applications. It is also to ensure all sectors of the economy, including for-profit, nonprofit, and government organizations, adopt CAS technologies. In other words, ensuring most organizations in most industries are transformed by these technologies. Successful development and adoption in Europe will likely lead to enormous benefits, not the least of which include the potential return to the kinds of robust rates of productivity growth Europe enjoyed from 1980 to 1995 that eliminated the gap in productivity with the United States.[27] Moreover, CAS adoption will help address pressing EU challenges, including in the areas of education, environment, health, and transportation. And if through the process of CAS adoption more CAS development (research and development, design, and production) takes place in Europe, that will boost EU global competitiveness.

Nations and regions that embrace CAS will reap significant benefits and gain competitive advantage over nations that do not.

Going forward, therefore, the foundational question for Europe—both the EU and its member states—will be: Does Europe embrace or resist CAS adoption? And if it embraces it, are political leaders willing to make this a top priority above many other concerns, including funding for public investment? This matters greatly because nations and regions that embrace CAS will reap significant benefits and gain competitive advantage over nations that do not.

There are two key factors in assessing where Europe stands: its CAS-producing firms and its CAS-using firms. With regard to the former, information technology firms are not uniform, as they differ in terms of type of technology and business model. One useful typology is to divide firms into those for hardware, those for software, Internet platform companies, and IT-based business service firms. CAS-producing firms include semiconductor manufacturers (e.g., ARM, Intel, Infineon, NXP, STMicroelectronics) and manufacturers of devices (e.g., Apple, Ericcson, Nokia, Schneider Electric) such as computers, displays, services, smartphones, etc.. Software firms include business solutions (e.g., Adyen, B&R, Dassault Systemes, Oracle, SAP, Wolters Kluwer) and consumer-facing ones (e.g., Microsoft). Internet platform companies include search (e.g., Google), social media (e.g., Facebook, Twitter, Viadeo), applications (e.g., Spotify, Uber,), and e-commerce firms (e.g., Amazon, eBay, Schwarz, Zalando). IT-based business service firms (e.g., Accenture, Atos) help other firms adopt and adapt IT solutions. Most companies span more than one industry (e.g., SAP provides both software and business services).

Where Does the EU Stand Vis-à-Vis Digital Technologies?

While Europe benefited considerably from the last technology wave (e.g., computing, Internet, mobile, cloud, etc.) it faces several challenges. First, as is widely known, many of

Europe's information technology firms largely missed this wave, with U.S. information technology firms (and not only the so-called GAFA [Google, Apple, Facebook, and Amazon] but many others as well) and to a somewhat lesser extent Chinese firms, gaining strong global market-leading positions. To be sure, some European information technology firms, such as SAP, innovated and adapted. And others, such as Skype and Spotify, were successful entrepreneurial tech start-ups. But overall, European firms did not capture the wave as successfully as U.S. and Chinese firms.

There are many reasons explaining why more European firms did not capture significant global market positions, including a lack of understanding of the importance of new "ecosystem-based" business models (e.g., Apple took market share from Nokia in part because it was able to leverage technology to create a unique customer experience leveraged through a product-service, ecosystem-based business model);a focus on mechanical engineering at the expense of software capabilities (as Marc Andreesen famously stated, "software is eating the world"); difficulty in supporting disruptive business models that allow new entrants to transform into "unicorns"; and, finally, the lack of an integrated EU market that would have enabled firms to gain scale quickly—something that is at the core of success for digital firms that have high fixed costs and low marginal costs and whose businesses often benefit from network effects.[28] For the emerging CAS, system scale also matters for many industries and firms because successfully developing digital technologies requires relatively high fixed costs—particularly those for R&D and software engineering. The more customers these costs can be amortized over, the more successful a company will become, earning profits it can reinvest in the next generation of products or services.

Development of Information and Communication Technologies

Before discussing Europe's position regarding digital technology industries, it is worth noting that there are several terms used to describe these industries, including digital industries, information technology industries, and ICT. The latter is perhaps the broadest, as it includes not just digital services firms, but also information technology hardware firms and communications services firms (e.g., Internet services providers and wireless providers). For this reason, this report will mostly use the term ICT to refer to the broad suite of industries involved in producing ICT products or providing ICT-based services. Of course, many "traditional" industries are becoming digital industries, as they adopt more ICT goods and services, and their offerings become more digitally based. More products (e.g., connected vehicles, smart electric grid, etc.) are becoming digitally enabled, and more processes are being powered by digital technologies (e.g., smart agriculture). But for the purposes of this report, ICT firms are those whose major output is information and communications goods and services.

There are a number of indicators of innovation industry success—not just for digital industries, but for all innovation-based industries. One is R&D. The EU lags behind other nations, including Japan, the United States, and China, in total R&D as a share of GDP (see figure 4). Likewise, the number of companies in the EU that are among the world's top 2,500 R&D-investing companies (per $100 billion of GDP) lags behind that of the

United States and Japan, and is on par with China (see figure 5). And the R&D intensity (R&D as a share of sales) of these companies is lower in the EU than in the United States (see figure 6).

Figure 4: Gross Domestic Expenditure on R&D as a Percentage of GDP, 2016[29]

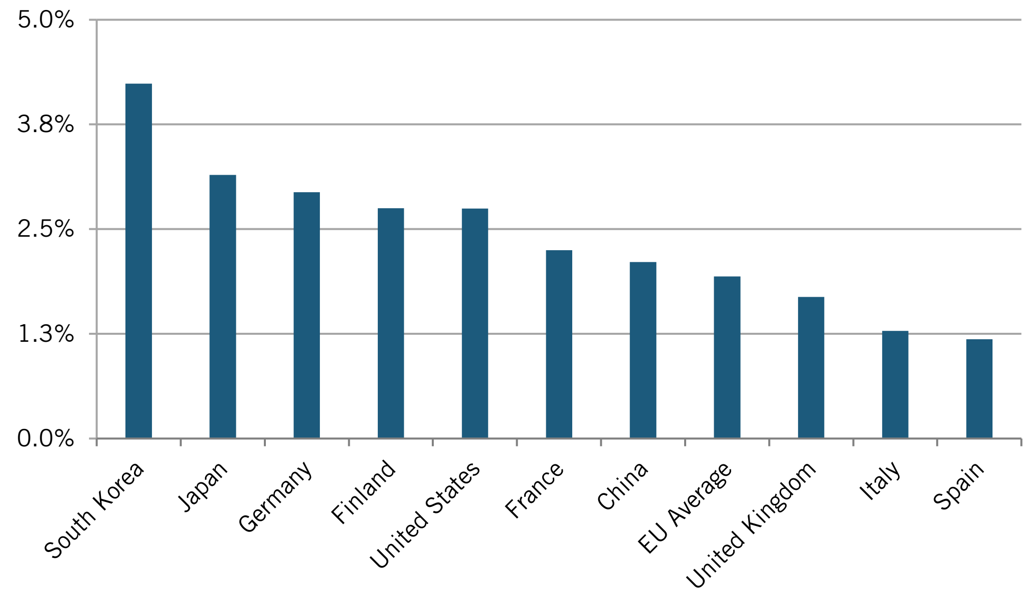


Figure 5: Number of Companies Among World's Top 2,500 R&D Investors per $100 Billion of GDP, 2016[30]

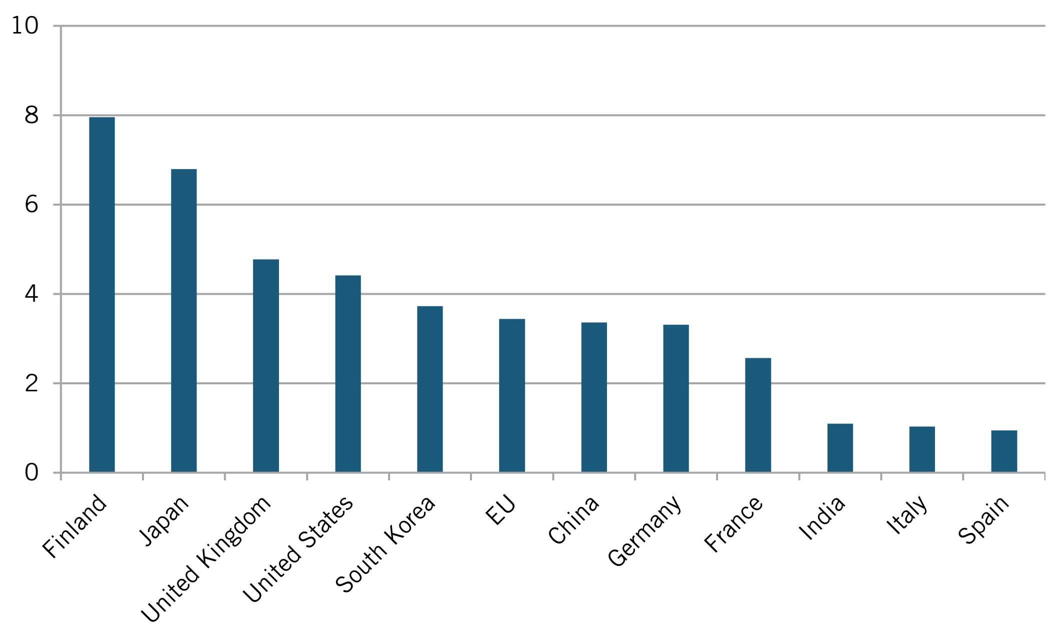
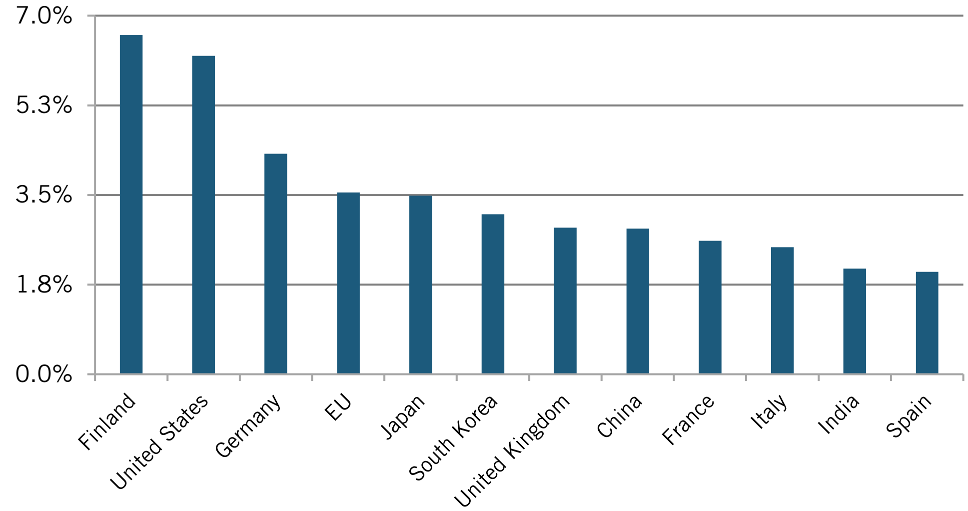


Figure 6: Average R&D Intensity of Enterprises in EU Industrial R&D Investment Scoreboard, 2017[31]



When it comes to ICT industry investment in R&D, companies in the United States invest almost three times more than companies in the EU and China, on average, with Japan investing at a little more than double the EU's rate, as figure 7 shows. South Korea (based on leading companies such as Samsung), as well as Finland, lead the ICT sector in overall business R&D as a share of GDP . Similarly, as figure 8 shows, the United States and Japan lead slightly in terms of the size of the ICT sector, with South Korea leading on this indicator overall.

Figure 7: Business R&D in the ICT Sector as a Percentage of GDP, 2015[32]

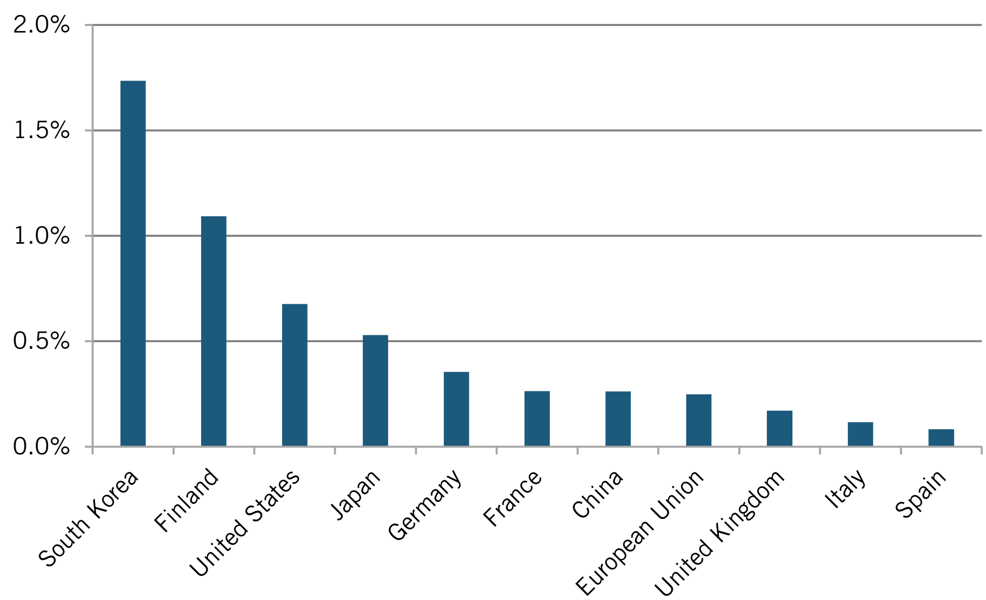
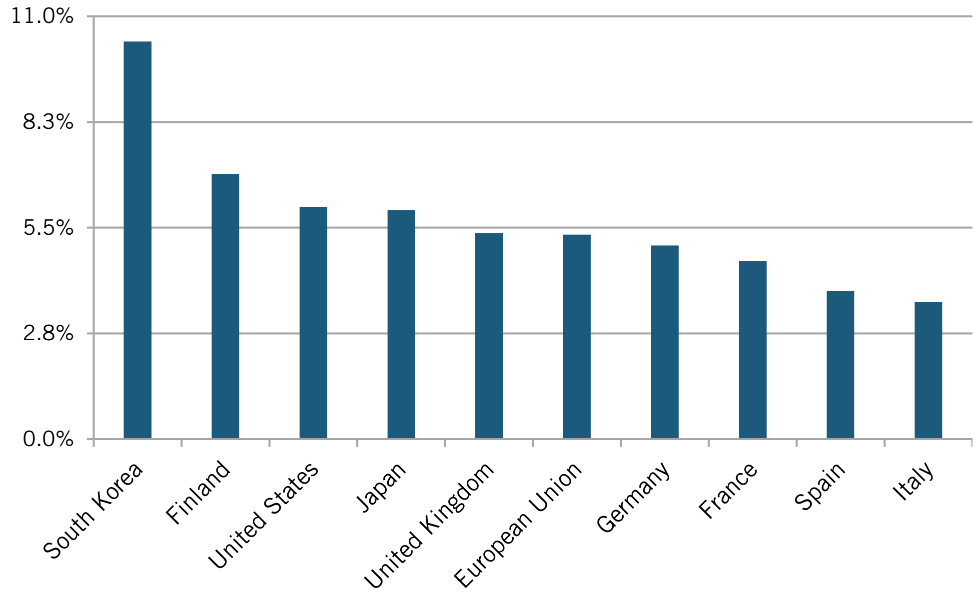
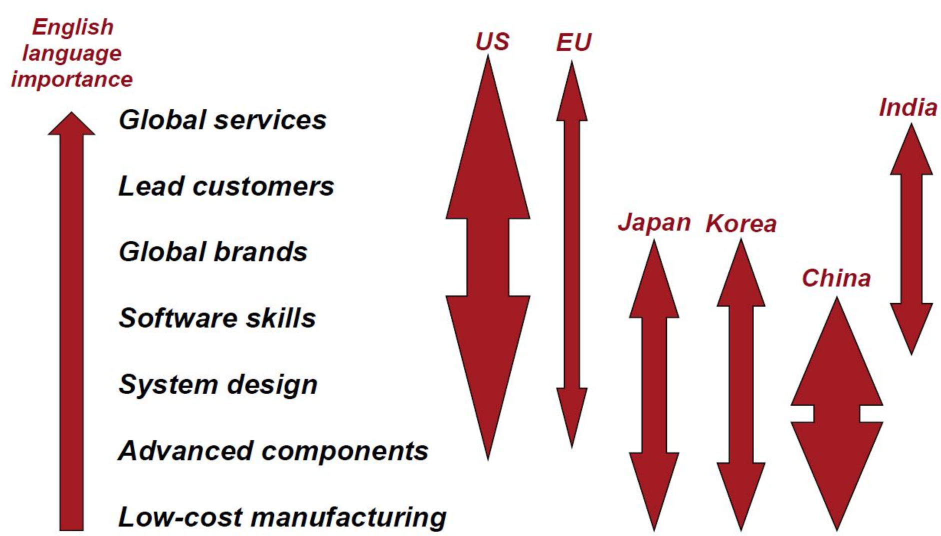


Figure 8: Value Added in the ICT Sector as a Percentage of Total Value Added, 2015[33]



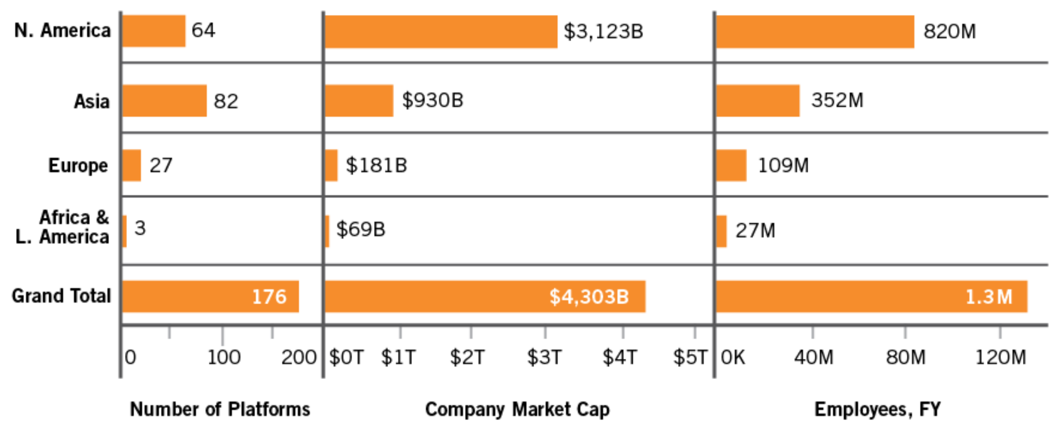
As David Moschella wrote in *Seeing Digital*, Europe competes across most of the technology stack (from hardware to applications and services), but not always as successfully as it would like (hence the thin line in figure 9). In other words, while Europe and the United States both have a presence across the technology stack of what Moschella has defined as global services firms, lead customers, global brands, software skills, system design, and advanced components (unlike China and India, which have major strengths, albeit confined to fewer areas), Europe's overall strength in all areas is less than that of the United States.[34]

Figure 9: National IT Strengths and the IT Stack[35]



For example, as shown in figure 10, while in 2016 Europe had 27 digital platforms with 109,000 employees in fiscal year 2105 and a combined market capitalization of $181 billion, the Asia-Pacific region had 82 digital platforms with approximately 350,000 employees and a combined market capitalization of $930 billion, and North America had 82 digital platforms worth over $3 trillion, with most being American. Likewise, a study of artificial intelligence start-up companies around the world estimated that in 2018 the United States was home to 1,393 AI companies, with Europe home to 769, China 383, and Japan 113.[36] European firms include companies such as Tangent Works in Belgium, Unsilo in Denmark, HeadAI in Finland, DCBrain in France, 12k Research in Germany, AImotive in Hungary, Artomatix in Ireland, Holsys in Italy, 904 Labs in the Netherlands, Aisens in Poland, Epinium in Spain, and Veridict in Sweden.[37]

Figure 10: Digital Platform Companies by Region, 2015[38]



Per GDP, the United States also files about twice as many ICT patents under the Patent Cooperation Treaty (generally more important patents than those filed only in individual nations), than Europe, while China files about 2.5 times as many, and Japan 4 times as many (see figure 11). Moreover, as figure 12 shows, relative to GDP, the United States has vastly more technology unicorns (privately held technology start-up companies valued at over $1 billion) than Europe, Japan, and China each of which has fewer unicorns than would be expected, controlling for the size of their economies. And venture capital investments in the United States as a share of GDP are approximately 10 times higher than in the EU and about one-third higher than in China, as figure 13 shows.

Figure 11: Patent Cooperation Treaty Patents Filed in ICT per Billion USD of GDP, 2014[39]

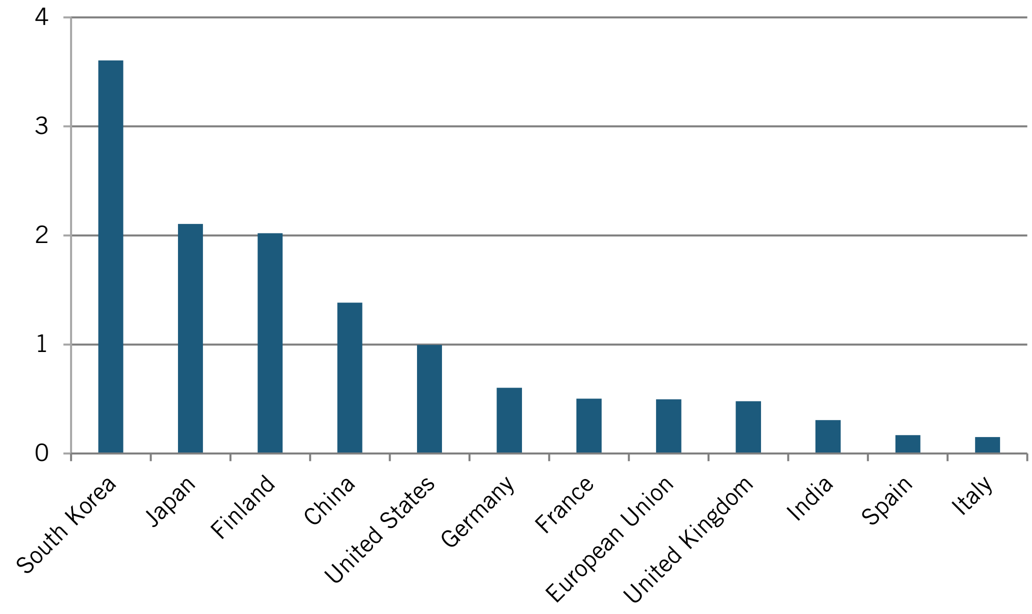


Figure 12: Number of Tech Unicorns and Exits/GDP (GDP Figures in $ Millions)

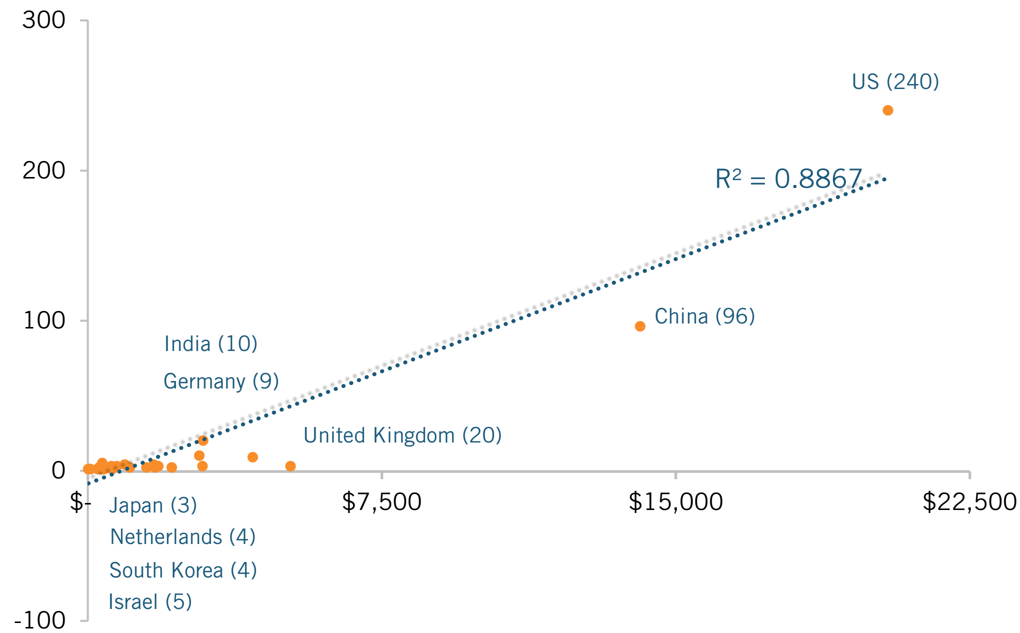
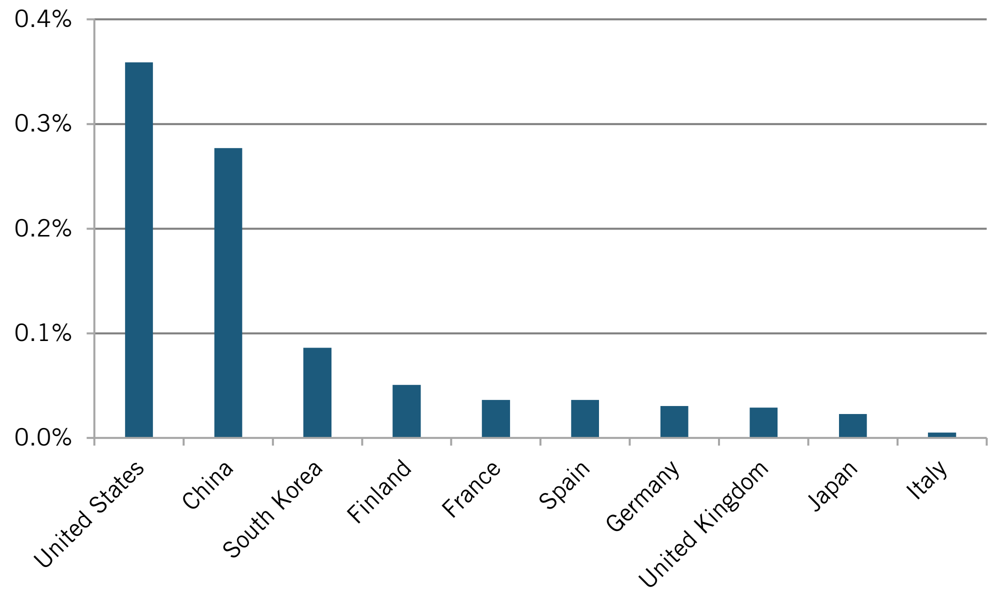


Figure 13: Venture Capital as a Percentage of GDP, 2016[40]

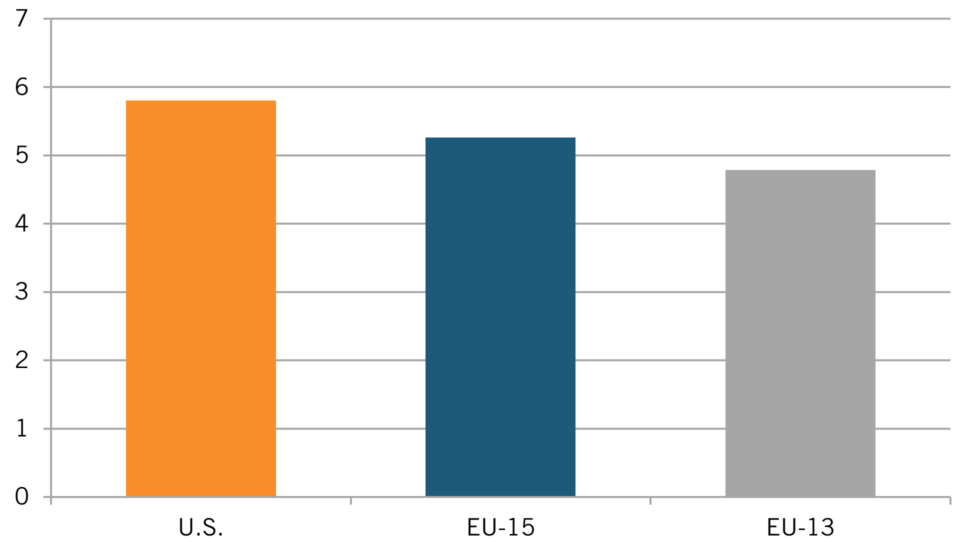


Adoption of Digital Technologies

Supporting the growth of ICT firms is important, but to drive economic growth it is even more important to ensure widespread and robust adoption of digital technologies across all sectors of the economy. Moreover, as much as the focus today is on ensuring most industries adopt the next wave of CAS technologies (e.g., technologies such as artificial intelligence, the Internet of Things, autonomous systems, blockchain, etc.), Europe has been slow to fully adopt the current wave of technologies.

A number of indicators illustrate the EU's lagging position. For example, the 2016 World Economic Forum's Networked Readiness Index survey showed the EU-15 and EU-13 nations trailing the United States in digital technology adoption, business-to-business Internet use, business-to-consumer Internet use, and staff digital technology training, as figure 14 shows.[41]

Figure 14: Average Score of 4 Indicators of Business Use of Digital Technologies Use (1–7, Where 7 is Highest Use)[42]



Likewise, U.S. digital technology investment is significantly higher as a share of total investment than most EU nations, as figure 15 shows. The United States is also ahead of Europe in the adoption of digital technology services. Van Ark wrote,"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."[43] Similarly, digital technology investment as a share of GDP is about 20 percent higher in the United States and Japan than in the EU, as figure 16 shows.

Figure 15: ICT Investment as a Share of Total Investment, 2016 (or Latest Data Available)[44]

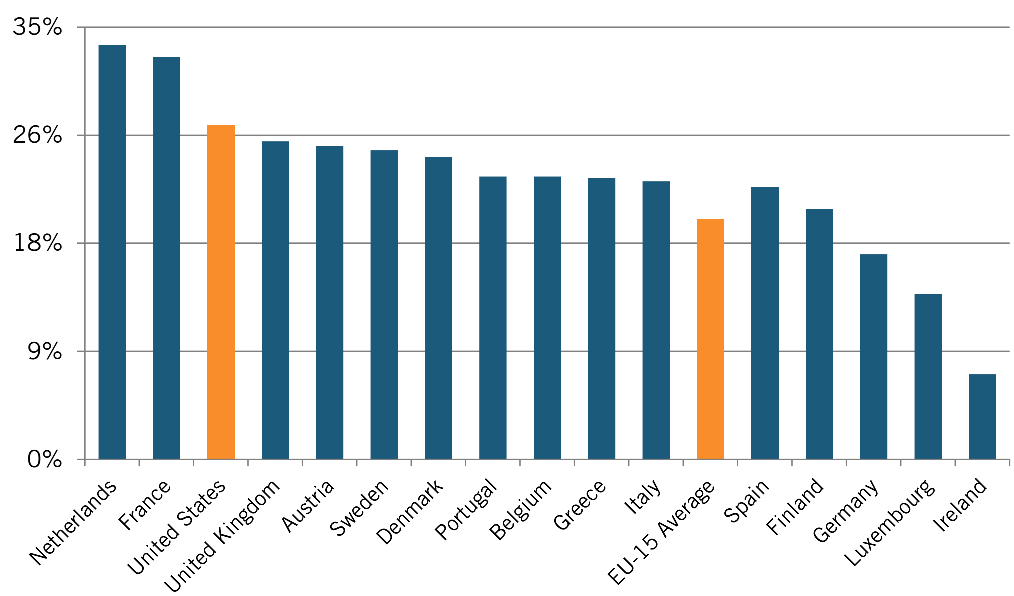
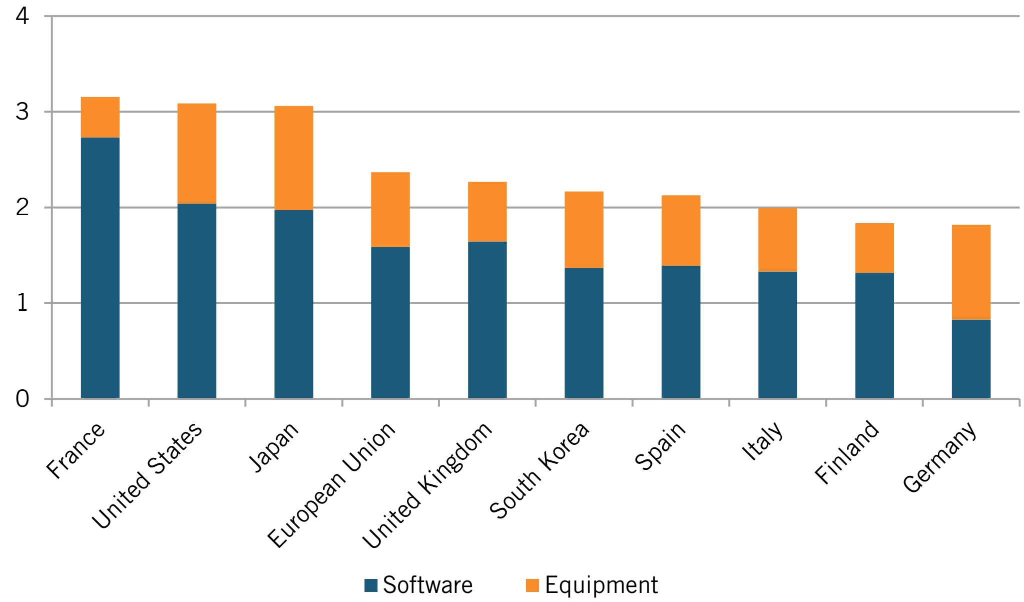


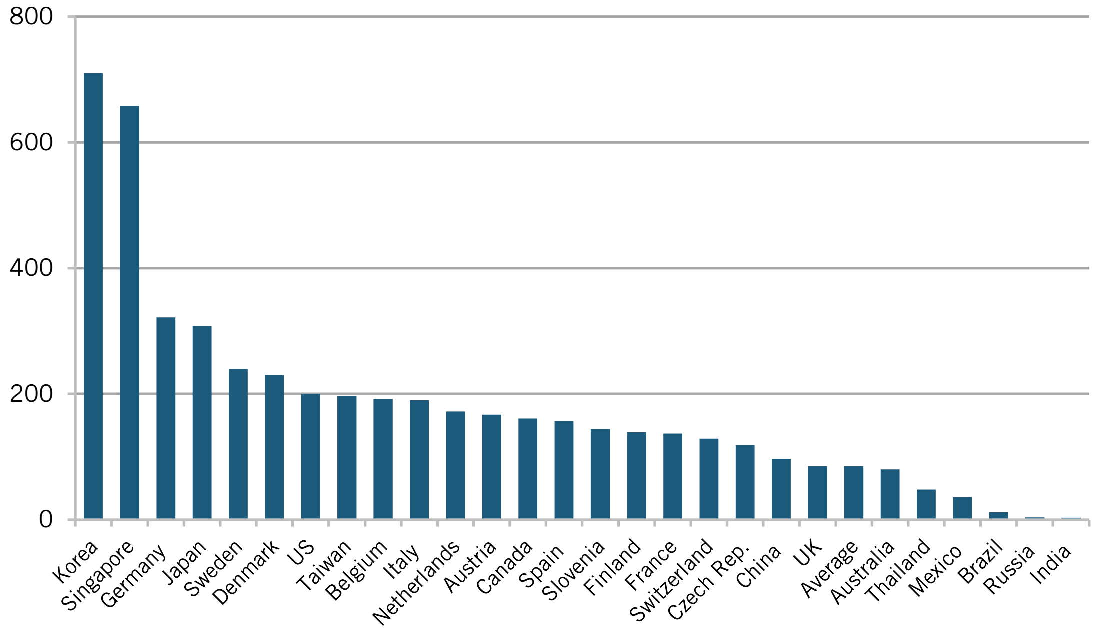
Figure 16: ICT Investment by Capital Asset as a Percentage of GDP, 2015[45]



The EU also appears to be behind the United States in cloud computing adoption. One study estimated that "the United States will be the largest market for public cloud services, accounting for more than 60 percent of worldwide revenues throughout the forecast with total spending of $163 billion in 2021. Western Europe will be the second-largest region with 2021 spending levels of $52 billion."[46] In other words, as a share of GDP, by 2021, U.S. spending on cloud computing services is projected to be over two times greater than western European spending as a share of GDP.

When it comes to industrial robot adoption, the United States outperforms Europe as a whole. South Korea was the world's largest adopter of industrial robots in 2017, with 710 robots per 10,000 workers, Germany was third with 322 robots, Japan was fourth with 308, and Sweden was fifth with 240. The United States ranked seventh with 200 industrial robots per 10,000 workers. Belgium, Italy, the Netherlands, Austria, Spain, Slovenia, Finland, France, the Czech Republic, and the United Kingdom all lag behind the United States (see figure 17).

Figure 17: Robots per 10,000 Manufacturing Workers, 2017[47]



Moreover, notwithstanding the emergence of artificial intelligence, robotics, and the Internet of Things, European productivity growth has slowed, and continues to lag behind U.S. productivity growth rates, as figure 18 shows.[48] Since the financial crisis, labor productivity in the 28 EU member states has grown just 0.7 percent annually. Only one EU-15 country, Ireland, has managed a higher productivity growth rate than that of the United States since 1995. Moreover, compared with the United States, Europe has experienced far smaller productivity gains from digital technologies. Although the contribution of digital technology 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 (see figure 19).

Figure 18: EU-15 and U.S. Average Annual Labor Productivity Growth, 1980–2017[49]

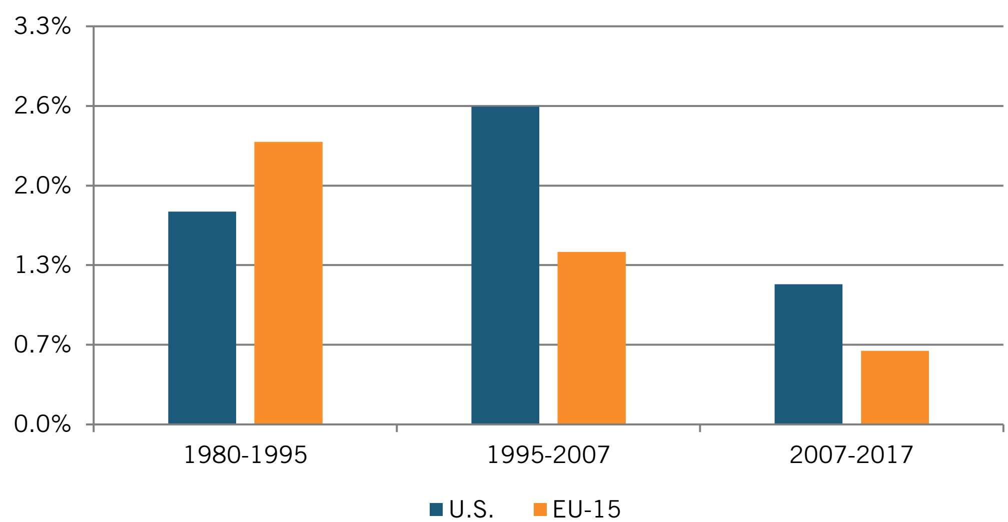
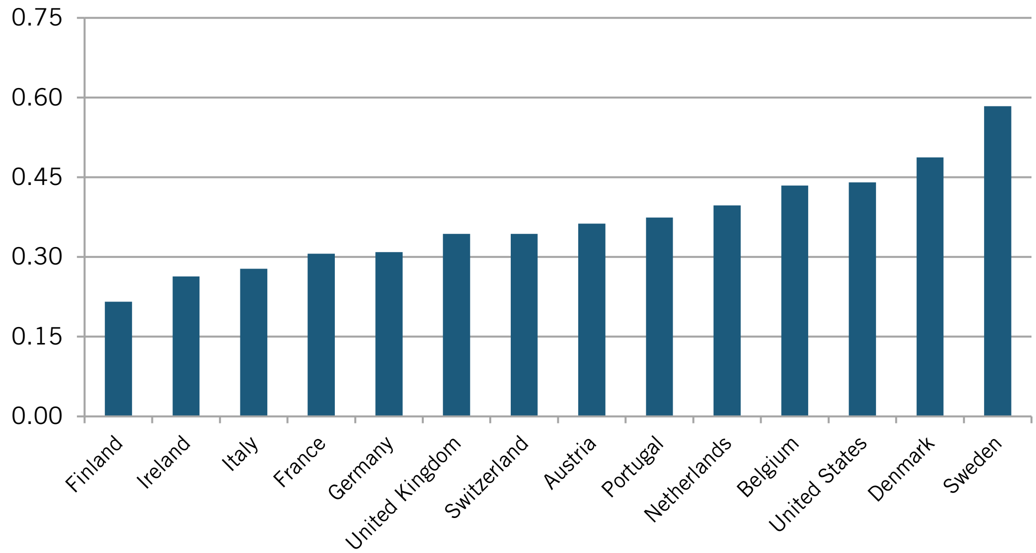


Figure 19: ICT Contribution to Average Annual GDP Growth Rate, 1985–2016[50]



China is both building up its domestic S&T capacity and harvesting the S&T competencies of others.

Innovation Policies and Systems Targeting CAS

Most developed and developing nations are putting in place policies to support CAS development or adoption—or both. This section examines innovation policies and systems, especially those related to the development and use of current and next wave ICT technologies in Europe, China, Japan, and the United States—although many other nations including Canada, India, South Korea, and Taiwan are actively seeking competitive advantage in advanced digital technologies. Indeed, global CAS competition will only increase. Europe and Japan largely missed the last transformation from mainframes to PCs and the Internet. China initially was not ready, but caught up through proactive policies that supported the development of its own indigenous digital technology firms. Today, more nations understand the evolving contours of CAS, and as such, if they fail to capture CAS competitive advantage, it will likely not be for lack of understanding. Rather, it will be for other reasons: lack of full support for the transformation; organizational, cultural, and institutional factors making it more difficult to innovate; and weak or poorly designed government policies.

China

The Chinese government is driven by an animating ambition to become the world's leader in science- and technology- (S&T) based industries, both for the purposes of achieving global economic leadership and to rival, if not surpass, the military capacity of the United States. A preponderance of China's leaders are educated in S&T fields, and thus have a deep appreciation of how science and technology underpin economic and military prowess. Further, China's leaders have proven unabashed at leveraging every tool at their disposal to turbocharge S&T-based economic growth, including by providing hundreds of billions of dollars in subsidies for advanced-technology industries and implementing supporting policies (e.g., government-funded research, support for digital-based infrastructure, export financing, etc.).

China has also put in place "innovation mercantilist" policies designed to compel foreign enterprises, including European ones, to transfer technology, know-how, and intellectual property (IP) to Chinese companies—and migrate advanced manufacturing activity there. In other words, China is both building up its domestic S&T capacity and harvesting the S&T competences of others. Also, it is important to understand that China has invested considerable sums of money to achieve this goal, including generous subsidies to individual firms. The Chinese strategy to dominate technology fields is to spend as much and to do whatever it takes.

China's latest innovation strategy is described in its *Made in China 2025* plan, which identified 10 key technologies the Chinese government intends to focus on and gain market share in. For instance, with regard to digitally enabled manufacturing (i.e., smart manufacturing), the strategy calls for Chinese firms holding 80 percent domestic market share of high-end computer numeric-controlled machines by 2025; 70 percent for robots and robot core components; 60 percent for big data; 60 percent for IT for smart manufacturing; and 50 percent for industrial software.[51] China's goal is for its companies to ultimately supplant foreign technology companies both in China and in markets around the world.[52] In other words, China seeks not comparative (or even competitive) advantage in global S&T industries, but rather absolute advantage that results in its ability to meet domestic demand with domestic production, and to gain a considerable share of global markets.

The weaknesses of China's S&T system rest primarily in the fact that China's headlong push for S&T leadership results in a substantial misallocation of resources, whether in redundant efforts to build semiconductors or life-sciences facilities and enterprises across multiple competing provinces, or in the production of publications and patents that are of dubious quality. Many of these technologies will find their way into state-owned or state-supported enterprises that do not have to compete on true market-based terms and thus are not likely to be as competitive as the global leaders in their fields. Misallocation of capital is likely a major reason why total Chinese factory productivity actually fell around 1.5 percent per year from 2007 to 2012.[53]

More generally, China's assertive use of mercantilist techniques to grow S&T-based industries is now engendering significant pushback from countries negatively impacted by such practices, which is likely to constrain China's "going-out" strategy of tapping into global markets to support an export-driven economic growth strategy (as we are seeing today with the Trump administration's tariffs on Chinese imports and other policies to pressure the Chinese government to roll back its innovation mercantilist policies, and the increasing number of other nations taking action regarding Chinese inward direct investment).

For over a decade, China reassured the world that it was embracing a path of "rebalancing" to become more dependent on domestic consumption and less on investment and exports.[54] But that has not come to pass, particularly after Xi Jinping became president. President Xi has reinforced China's focus on trying to grow through changing its industrial composition to higher-value-added export-oriented sectors. While that may generate some gains, particularly over the next decade or two, it is not a sustainable path to growing the Chinese economy, in large part because advanced industries can never be a large enough share of a nation's GDP to overcome slower growth in the rest of the economy. Indeed, research from the McKinsey Global Institute found that countries that outperform their peers economically do not have a more favorable sector mix (e.g., more high-tech industries), but instead have individual firms across all sectors that are more productive.[55] Moreover, in many cases, Chinese policies to support advanced industries come at the cost of higher productivity growth in the rest of the economy, especially in policies that limit access to global best-in-class technology, such as tariffs and incentives, and pressures to buy lower-quality domestic technology. As such, China should, but likely will not, focus more on raising productivity across the board in all sectors.

China has launched a major effort to develop and deploy emerging digital technologies, including several Internet of Things initiatives. In 2011, China's Ministry of Industry and Information Technology (MIIT) issued a "Five-Year Plan for the Development of the Internet of Things," outlining how the government intends to support the technology, such as by setting standards and demonstrating real-world applications. This plan called for creating an Internet of Things "special fund" to support R&D, with investments totaling $774 million from 2011 to 2015. In August 2013, China's State Council issued guidance to support smart city pilot programs, with a particular focus on smart utilities and transportation; and the Chinese Development Bank agreed to establish financing programs for smart city pilots. Also in 2013, China established an interagency council to guide national policy on the Internet of Things and issued guidance to support the technology, including fostering industry development, workforce training, and R&D targets.

In May 2015, China's State Council issued a China Manufacturing 2025 strategy (i.e., *Made in China 2025)*, a 10-year plan laying out a strategy for the country to become a "world manufacturing power," especially by strengthening its intelligent manufacturing capabilities. On March 31, 2016, China's MIIT announced an Implementation Plan for the 2016 Intelligent Manufacturing Pilots Special Project, with the plan including a detailed timeline for intelligent manufacturing pilots in which companies are to upgrade their facilities with a range of intelligent technologies. The plan orders 60 pilot projects across a number of Chinese industrial sectors with the following directives:

- Leverage intelligent technologies to upgrade discrete manufacturing sectors (such as electronic information, machinery, aviation, aerospace, and automotive);
- Leverage intelligent technologies to upgrade process-manufacturing sectors (such as oil exploration and petrochemicals);

- Promote "network-cooperative manufacturing" in integrated circuits, communication products, machinery, automobiles, household appliances, and related industries; and
- Leverage cloud computing to carry out large-scale customization for digital products and other related sectors.

In April 2016, MIIT complemented the Intelligent Manufacturing Pilots Special Project with an Implementation Plan for 2016 Special Project on Innovatively Promoting the Integration of Industrialization and Informatization. The plan urges Chinese manufacturers to promote the incorporation of next-generation information technologies into their manufacturing processes. The plan seeks to build Internet-based service platforms to boost entrepreneurship and innovation, with the goal of over 50 percent of leading enterprises in key industries having access to such platforms; while also cultivating a batch of service platforms using cloud and industry big data and achieve a 20 percent annual increase in the number of "industry cloud corporate users."

To achieve these goals, the plan for Innovatively Promoting the Integration of Industrialization and Informatization outlines seven priority work streams, including beginning the development of cyber-physical systems (CPS) testing and evaluation platforms and verification test beds, launching CPS application pilots, and formulating CPS-related standards. Finally, in part to help fund these and other initiatives, in June 2016, China's National Development and Reform Commission, Ministry of Finance, and Ministry of Industry and Information Technology announced the launch of a $3 billion (¥20 billion) fund that will invest in the advanced-manufacturing sector, promote modernization of traditional industries, and boost high-end manufacturing. The funds were contributed by China's central treasury, its State Development and Investment Corporation, and the Industrial and Commercial Bank of China.

As part of *Made in China 2025,* China is also launching a network of Manufacturing Innovation Centers (MICs) modeled directly after America's Manufacturing USA initiative. In fact, the first two Chinese institutes, focused on additive manufacturing and wide-bandgap power electronics (or, power batteries), were a copy of America's first two Institutes of Manufacturing Innovation. By 2020, based on China's 13th 5-Year National Plan, the number of MICs is expected to be 15—and by 2025 China intends to grow the number of MICs to 40.[56]

In short, China's government has instituted several key initiatives and made significant investments toward ensuring the country's manufacturing industries adopt and embrace smart manufacturing technologies and processes as quickly as possible. As Paul Tate, an analyst for market-research firm Frost and Sullivan, observed, "Overall, the aim of this new strategy [*Made in China 2025*] is to put China on par with other industrialized countries such as the United States and Germany … in accelerating the adoption of digital technologies and advanced production approaches." Table 1 summarizes the strengths, weaknesses, opportunities, and threats of China's S&T system.

Table 1: SWOT Assessment of China's S&T System

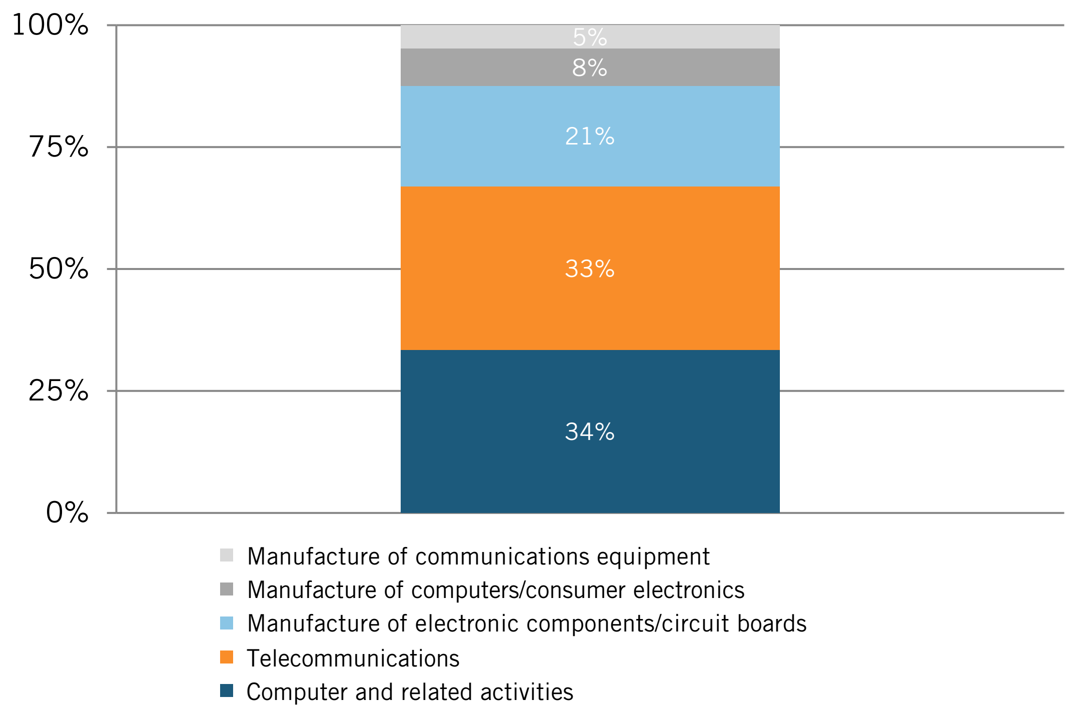
Strengths	Weaknesses
▪ National mission of achieving global technology leadership ▪ Massive government investment in S&T ▪ Ability to acquire foreign technology without paying for it, including through cyber vectors and using large domestic market to compel technology transfer ▪ Robust build-up of new technology-based military weapons ▪ Large numbers of science and engineering (S&E) graduates ▪ Reverse engineering, fast following, absorptive capacity ▪ Large domestic market making it compelling for foreign innovation-based companies to invest in China	▪ Weaker at original, "first-to-world" innovation ▪ Questionable ability of regulatory regime to validate safety/efficacy of cutting-edge projects (e.g., issues around shoddy high-speed rail, counterfeit pharmaceuticals, etc.) ▪ Overall poor quality of patents (although improving) ▪ Scientific publications infrequently cited ▪ Few world-class universities ▪ Science funding system not based as much on merit and peer review ▪ Overinvestment in some sectors leading to overcapacity and wasted capital ▪ Dominance of state-owned enterprises crowding out more innovative and efficient private enterprises ▪ Education system not instilling creative thinking ▪ Relatively poor corporate management skills ▪ Lack of capabilities higher in the "ICT stack," especially ICT services ▪ Lack of well-perceived global brands
▪ Raising of strengths at original innovation ▪ Widespread adoption of ICT across all sectors ▪ Translation of investments in emerging sectors—semiconductors, life sciences, robotics, and clean energy—into global leadership ▪ Use of power and funding to shape international and national economic policies/institutions (e.g., World Bank; Asian Infrastructure Development Bank; One Belt, One Road initiative)	▪ Aggressive "innovation mercantilism" having triggered responses from other nations, thereby limiting China's access to markets and possibly provoking new trade and security arrangements ▪ Rising costs shifting lower-skilled production to lower-cost nations ▪ Difficulty in moving up innovation value chain ▪ Overinvestment and waste threatening financial stability; too much low-quality debt
Opportunities	**Threats**

Notwithstanding the growth of China's ICT firms and the focus of the Chinese government on these sectors, overall ICT use lags behind global leaders, in large part because China is still a developing economy. China ranked 65th out of the 193 countries ranked in in the *2018 United Nations E-Government Development Index*.[57] According to another recent study, China ranks 141st among 200 countries tested in average broadband speeds.[58] In 2016, 53 percent of individuals used the Internet, compared with 90 percent in the Netherlands and 94 percent in Japan.[59]

Japan

Japan's ICT industry accounts for 9 percent of Japan's GDP and 7 percent of its employment (4 million workers).[60] In 2015, Japan's share of the ICT world market stood at 10.9 percent, a 1.4 percent decrease from the 12.3 percent share it commanded in 2013.[61] Copy machines, liquid-crystal TVs, and notebook PCs comprise the three ICT goods sectors in which Japanese manufacturers command the largest share of global markets. Computers, telecommunications, and the manufacture of electronic components/circuit boards account for close to 90 percent of the value added by Japan's ICT sector, as figure 20 shows. However, Japanese ICT manufacturers have been steadily losing global market share in ICT product categories across the board, which may suggest that Japan's ICT sector is shifting towards services—although Japan has been losing global share in virtually all ICT services sectors except for hardware product support since 2011.[62] Employment in Japan's ICT goods manufacturing sectors has declined 20 percent since 2011.[63]

Figure 20: Distribution of ICT Sector Value Added by Manufacturing and Services Sub-sectors in Japan, 2011[64]



Nevertheless, the Japanese government expects Japan's ICT industry to increase in value before 2020, with much of the growth expected to come from the Internet of Things sector, as Japanese network operators create partnerships with foreign device manufacturers, providing domestic and export customers with cost-effective solutions.[65]

Japanese enterprises have lagged behind global peers in leveraging ICTs as a platform for innovation, including the creation of new products, services, and ICT-enabled business models. In fact, Japanese companies have traditionally used ICTs to cut costs, not increase profits, with only 16 percent of Japanese corporations reporting that they use ICTs to raise profits.[66]

Japanese enterprises have lagged behind global peers in leveraging ICTs as a platform for innovation, including the creation of new products, services, and ICT-enabled business models.

In June 2014, Japan's Ministry of Internal Affairs and Communications (JMIAC) issued "A Declaration to be the World's Most Advanced IT Nation" and released the *Smart Japan ICT Strategy* as the country's new national ICT Strategy roadmap. The *Smart Japan ICT Strategy* features two co-equal components: "The ICT Growth Strategy II"—which is domestically focused on "creating new innovations by connecting various things and services with ICT"—and the "Initiative on Intensification of International Competitiveness and Global Outreach in the Field of ICT," which focuses on enhancing the competitiveness of Japan's ICT product manufacturers and ICT services players in global markets.[67] The internationalization component of the *Smart Japan ICT Strategy* aims to increase annual overseas sales of ICT goods and services to ¥17.5 trillion ($147 billion) by 2020 (which would double the $73 billion of ICT goods exports Japan shipped in 2012).[68]

In 2016, the Japanese government enacted its *5th Science and Technology Basic Plan*. One key focus was on CAS technologies, which they refer to as a "Super Smart Society, the Society 5.0."[69] The focus will not just be on industry, but CAS adoption in many sectors, including health care, cities, and transportation. Japan sees its vision of Society 5.0 as "balancing economic advancement with the resolution of social problems by incorporating new technologies such as Internet of Things, robotics, AI, and big data in all industries and social activities," providing goods and services that equitably address social needs.[70] At least 14 Japanese ministries are involved in executing various facets of Japan's Society 5.0 transformation.

Japan's National Institute of Information and Communications Technology has identified five key research focus areas for Japan's Society 5.0 vision. These include: 1) Sensing fundamentals (e.g., remote sensing); 2) Integrated ICT infrastructure (e.g., wireless networks, photonic networks, innovative networking, etc.); 3) Data utilization and analytics platforms (e.g., multilingual speech translation, computational neuroscience and brain ICT interfaces, social knowledge analysis, etc.); 4) Cybersecurity (e.g., next-generation cyberattack analysis, lightweight cryptography and authentication, etc.); 5) Frontier research (e.g., optics, quantum engineering, nanotechnology, biotechnology, etc.).[71]

Japan's *ICT Strategy* recognizes the foundational role the application of ICTs plays in boosting the productivity and innovation potential of all Japanese industries, noting

"The utilization of ICT is one of the key means of boosting the growth of Japan's economy, and of contributing to global society."[72] Japan's *ICT Strategy* calls out seven ICT-enabled Important Projects to be carried out by industry, academia, and government: 1) Data utilization; 2) Broadcast/contents; 3) Agricultural value chains; 4) Regional revitalization; 5) Disaster prevention; 6) Medicine, nursing, and health; and 7) Natural resources.

In terms of leveraging ICT assets for innovation, Japan's *ICT Strategy* sets four priorities: 1) promotion of open data, such as utilizing geospatial information; 2) strengthening of cybersecurity (including the establishment of the Cybersecurity Research Center); 3) building world-class ICT infrastructure; and 4) promotion of R&D to create innovation.[73]

While many have attributed the influence of Japan's Ministry of International Trade and Industry (MITI) with playing a decisive role in the creation of the leading sectors of Japan's economy post-World War II, the reality is MITI's role in shaping the information technology sector was much less pronounced than in other sectors such as automotive, steel, shipbuilding, or even consumer electronics. As Justin Bloom wrote in *Japan's MITI as a Policy Instrument in the Development of Information Technology,* "MITI has been a relatively small participant in influencing the course of development of information technology through direct financial support of R&D in this field."[74] In fact, by 2014, MITI "had practically given up on the idea of industrial policy in the fast-changing ICT sector," according to Dr. Stefan Lippert, a professor of International Business Studies at Temple University's Japan Campus.[75] This does not mean MITI has given up on supporting Japan's ICT industries—indeed, it is providing hands-on support to firms and cultivating professional human resources in conjunction with JMIAC and helping to establish bases of ICT security evaluation and certification for critical infrastructures—although it has gotten out of the business of directing development of the sector.[76]

Public investment in ICT R&D in Japan totaled $4.2 billion in 2014, equating to 9.08 percent of total Japanese public R&D investment (and 0.071 percent of Japanese R&D).[77] In the private sector, ICT investment reached $29.7 billion in 2011, with ICT-related R&D accounting for 23 percent of all R&D conducted by Japanese enterprises.

JMIAC serves as the lead government agency "promoting [the] ICT research and development that maintains and expands the vitality of Japan's ICT industry."[78] Current ICT R&D priorities for JMIAC include big data; communications platform technologies for smart grids; high-speed, large-capacity, and low-power optical network technology; electromagnetic wave sensing technologies; neural information communications technologies; technologies for achieving ICT networks that are resilient to disasters; and space communications technologies.[79]

JMIAC administers several programs designed to turbocharge ICT-enabled innovation in Japan. For example, the "INNOvation Program" ("inno" actually means "unusual talent" in Japanese), promotes "challenges by disruptive-creative persons who are not bound by traditional thinking" while the Strategic Information and Communications R&D

Promotion Programme (SCOPE) funds innovative research topics submitted from universities or companies. JMIAC has also made available its test bed network that integrates elemental technologies for next-generation networks to drastically resolve problems such as security and energy consumption.[80]

On October 1, 2013, Japan introduced a tax reform outline to stimulate private-sector investment that included a tax incentive to promote capital expenditure on productivity-enhancing equipment. Implemented through the Industrial Competitiveness Enhancement Act, expenditures on any machinery, tools, appliances, buildings, facilities, structures, or software used as "equipment for production" that qualifies as "productivity-enhancing equipment" can qualify for immediate 100 percent depreciation or a 5 percent tax credit; while expenditures on such items made after April 1, 2016, but before March 31, 2017, are eligible for 50 percent depreciation or a 4 percent tax credit.[81]

Japan's government has prioritized ICT as a key enabler of broader Japanese economic growth and driver of productivity and innovation across all industries. Japan's government has also endeavored to be a leading user of ICT-based solutions. Total public procurement of ICT products in Japan reached $18 billion (0.03 percent of GDP) in 2013.[82] Japan consistently scores among the top three comparator nations (with Singapore and the United States) in measures of e-government sophistication, such as the United Nations' E–Government Development Index, E-Participation Index, and Online Services Index. By 2012, Japan had made 7,188 applications, notifications, and other national administrative procedures available online, with 41.2 percent of all such forms submitted online.[83] To accelerate provincial application of e-government solutions, in 2014, JMIAC announced the ten guidelines to accelerate e-local government initiatives.[84] Japan is a member of the Government Procurement Agreement.

Japan's government has made the deployment of high-speed broadband a cornerstone of its national ICT strategy. At the end of March 2013, ultra-high-speed broadband services were available in 53.8 million, or 99.4 percent of all, Japanese households. Today, broadband services are available to 100 percent of Japan's 54.2 million households.[85]

Japan also adopted its Open Government Data Strategy in July 2012 and signed on to the G8 Open Data Charter in 2013.[86] However, in the Japanese government's action plan to fulfill its commitments to the charter, several key commitments were excluded, such as releasing data by default, applying open licenses to datasets, and releasing data for improved governance.[87] Although Japan has published a large number of datasets on its national data portal, many of them do not utilize machine-readable formats.[88] In an analysis of G8 countries' progress toward fulfilling their commitments to the charter, ITIF's Center for Data Innovation (CDI) ranked Japan sixth.[89] Japan ranked 10th out of 193 countries in government ICT use and efficiency in the 2018 *United Nations E-Government Development Index*.

Moreover, ICT deployments to enable smart cities are a key component of the *Smart Japan ICT Strategy.* Japan's Ministry of Economy, Trade, and Industry (METI)—the successor to

MITI—has been investing in smart city projects since 2010, with METI providing financial support to establish 10 Japanese “smart communities” in 2012 that feature integrated intelligent transportation systems, smart electric meters in homes and businesses, and smart electric grids incorporating renewable energy sources. The economic value of smart city business in Japan is expected to grow from ¥1.12 trillion in 2011 to ¥3.8 trillion ($30.5 billion) by 2020.[90] In particular, Japan has long been a global leader in the deployment of intelligent transportation systems.[91]

To make Japan the world’s most advanced IT nation, in 2015, the Japanese government announced plans to establish a council of public- and private-sector organizations that would support the development of specific Internet of Things technologies, including information-processing technologies that can analyze immense volumes of data collected from connected devices, and systems for safely disabling Internet-connected autonomous devices, such as self-driving cars, in the event of a safety or security risk. Japan also launched the Artificial Intelligence Technology Strategy Council in April 2016 to craft a roadmap for the development and commercialization of AI. Published in May 2017, this roadmap outlines priority areas for R&D, primarily focusing on the themes of productivity, mobility, and health. The strategy also encourages collaboration between industry, government, and academia to advance AI research, as well as stressing the need for Japan to develop the necessary human capital to work with AI.

With regard to digital technology education, as recently as 2007, it did not factor heavily into Japan’s national education policy. But by 2011, the Ministry of Education, Culture, Sports, Science, and Technology recognized the headway Japan needed to make with regard to ICT in education, rolling out The Vision for ICT in Education.[92] Under this vision, the Ministry targets information literacy— a compulsory subject in secondary schools—and knowledge deepening through ICTs.[93] The Ministry also released ICT guidelines for educators in 2010, with targets for each stage of a student’s development.[94] However, *The Japan Revitalization Strategy*, released by the prime minister’s office in 2014, fails to mention how ICTs will play a role in Japan’s education.[95] Table 2 offers a strengths, weaknesses, opportunities, and threats (SWOT) assessment of Japan’s science and technology system.

Table 2: SWOT Assessment of Japan's S&T System

Strengths	Weaknesses
▪ Third-highest national R&D intensity ▪ World's highest corporate R&D investment ▪ Third in researchers per capita and fourth in higher-education attainment, among 44 nations studied ▪ Strong base of medium-sized industrial firms: the *chuken kigyo* that command more than 70 percent of the world market in at least 30 technology sectors worth more than $1 billion ▪ Robust network of Industrial Technology Research Institutes (Kohsetsushi Centers) supports technology adoption and invention by manufacturing enterprises of all sizes ▪ Second-highest number of Nobel laureates in S&T fields ▪ Strengths in autonomous systems and robots	▪ Weak new-firm formation system ("organization man" culture stunts entrepreneurship) ▪ Low levels of venture capital ▪ Middling level of government R&D investment ▪ Middling level of quality scientific publications ▪ Very weak levels of foreign direct investment ▪ Relative weak ability to master software ▪ Relatively low levels of ICT use in industry ▪ Low productivity in services sectors ▪ Limited number of leading global ICT firms ▪ High corporate taxes ▪ Strict immigration policies impede ability to attract high-skill foreign workers, especially in the technology sector
▪ A leading developer and adopter of a number of advanced manufacturing product and process technologies, including robotics, industrial automation, 3D printers, and nanotechnology ▪ Government push to support key industrial and technology sectors	▪ Proved adept with a MITI-led industrial catch-up strategy through to the 1980s; has proven less adept at driving the frontier of innovation in fields such as ICT and biotech ▪ Continuing anemic broader economic growth environment; deflation and the lost decade ▪ Aging population will limit innovation and government investment ▪ China presents a challenge to many of its core industries
Opportunities	**Threats**

The United States

On an absolute basis, the United States retains the world's most robust science and technology ecosystem and infrastructure.[96] However, on a per-GDP basis, the United States is not the leader, and some global competitors are gaining ground fast.

To understand the U.S. innovation system, it is worth examining the history of the United States in terms of innovation and innovation policy.[97] For its first 125 years after independence, the United States was not at the global technology forefront—that advantage was held by select European nations: first the United Kingdom, and then Germany. However, with the emergence of the steel-based industrial revolution of the late 1890s, the United States joined the ranks of the world leaders, producing a host of leading-edge innovations. As business historian Alfred Chandler showed, the large American market enabled U.S. firms to successfully enter new mass-production industries, such as chemicals, steel, and meat processing—and later autos, aviation, and electronics.[98] Because scale mattered so much to innovation and firm competitiveness, U.S. firms such as DuPont, Ford, GE, GM, Kodak, Swift, and Standard Oil became global leaders.

Scale helped, but the United States had other advantages. One was the "greenfield" nature of development. Unlike Europe, which had to overcome a preindustrial, craft-based system, the American economic canvas was fresher, enabling new forms of industrial development to be more easily established. Another advantage was the unrelenting commercial nature of the American culture and system, wherein commercial success was valued above all else. As President Calvin Coolidge famously stated, "The business of America is business."

World War II provided an enormous boost to U.S. technological innovation, and helped drive the emergence of a more science-based system of innovation (inspired in part by Vannevar Bush, director of the U.S. Office of Scientific Research and Development during WWII) which would become dominated by large firms and the federal government. The establishment—initially in the Great Depression and then after the war—of large, centralized corporate R&D laboratories helped drive innovation in an array of industries, including electronics, pharmaceuticals, and aerospace. On top of that, the massive federal support for science and technology in WWII helped develop the "arsenal of democracy" the Allies used to beat back the Axis powers.[99] This strong federal role continued after the war, with substantial funding for a system of national laboratories and significantly increased funding of research universities. Federal funding for research helped drive innovation and played a key role in enabling U.S. leadership in a host of industries, including software, hardware, aviation, and biotechnology. For the most part, this research was funded through mission-based agencies seeking to accomplish a particular federal mission (e.g., defense, health, energy), and through a system of peer-reviewed basic research funding at universities.

Attempts by the federal government to explicitly support commercial innovation were at best made in fits and starts, and never really got off the ground. Moreover, they were not guided by an overriding vision or mission—unlike the government's efforts to develop defense and space technology—which were motivated by the need to respond to the Soviet threat. And they certainly were not linked to overall economic policy, which remained focused principally on reducing business cycle downturns and, depending on the political party in power, reducing poverty.

This system began to gradually change in the late 1970s with the emergence of competitiveness challenges from nations such as Japan and Germany. It was with the election of President Jimmy Carter in 1976 that the federal government began to focus in a more serious way on the promotion of technology, innovation, and competitiveness. The motivation for this was the major recession of 1974 (the worst since the Great Depression), the shift in the U.S. balance of trade from one of surplus to one of deficit, and the growing recognition that nations such as France, Germany, and Japan posed a serious competitiveness challenge to U.S. industry.

These efforts were followed by efforts by Congress and the Reagan and first Bush administrations. Policymakers responded with a host of major policy innovations, including passage of the Stevenson-Wydler Act (for federal lab reform), the Bayh-Dole Act, the National Technology Transfer Act, and the Omnibus Trade and Competitiveness Act. They created or reformed a long list of alphabet-soup programs to boost innovation, including Small Business Innovation Research (SBIR), an expanded National Technical Information Service (NTIS), a reformed Small Business Investment Company (SBIC), Manufacturing Extension Partnership (MEP), and cooperative research and development agreements (CRADAs). This legislation put in place the R&D tax credit and lowered capital gains and corporate tax rates. It also created a host of new collaborative research ventures, including SEMATECH; the National Science Foundation (NSF) Science and Technology Centers and Engineering Research Centers; and the National Institute of Standards and Technology (NIST) Advanced Technology Program. And they put in place the Baldridge Quality Award and the National Technology Medal.

U.S. industrial innovation and competitiveness gained renewed attention after a period of relative optimism in the mid-1990s and 2000s, followed by the manufacturing job losses of the 2000s, the Great Recession, and the emergence of robust new technological competitors, including, but not limited to ChinaBecause of this, the Obama administration established Manufacturing USA, a network of 14 cooperative industry R&D centers, increased funding for science agencies (including NSF, NIST, and Department of Energy); put in place policies to expand the number of science, technology, engineering and mathematics (STEM) graduates; and passed legislation to reform the patent system. Under the Trump administration, the main effort has been to push back against unfair Chinese trade policies.

However, partisan differences, fueled in part by growing populism from the Right and the Left (anti-government for the former; anti-corporate for the latter) coupled with a large federal budget deficit and a political unwillingness to raise taxes on individuals or cut entitlements, has meant progress to shore up the weaknesses in the U.S. innovation system has been extremely limited. Coupled with the dominance of neo-classical, free-market economists who decry innovation policy as intrusive meddling in the natural working of the economy, the result is a lack of a national, coordinated innovation policy system in the United States. While many nations (e.g., Finland, Germany, and Sweden) have developed national innovation strategies, as ITIF wrote in *The Global Flourishing of National Innovation Foundations*, the United States has not.[100]

Clearly the United States appears to have sustainable strengths in a number of areas, including managerial talent, enterprise use of ICT, and business cultural factors such as demanding customers and a collaborative culture.

In the United States, most commercial activities are conducted by private, for-profit firms. The United States generally does not support R&D directly in firms, unless that R&D is related to achieving a core mission, especially defense. For example, on a per-GDP basis, Korea invests 89 times more in industrially oriented R&D than the United States, 43 times more than Germany, and 15 times more than Japan.[101]

However, the federal government does support an array of policies to help firm-level innovation. For example, in 1981, Congress established a tax credit for business research and development expenditures. This provision, the first of its kind in the world, allowed companies to claim a 20 percent tax credit on increases in expenditures on research. In addition, the Small Business Innovation Research Program (which requires federal agencies to allocate a small share of their R&D budgets to small business research projects related to agency mission goals) was established in 1984. Likewise in 1984, Congress passed the Cooperative Research and Development Act, which allowed companies to gain an antitrust exemption when participating in precompetitive R&D consortia.

All of these measures are largely technology and firm agnostic, supporting innovation itself (e.g., the R&D credit). However, the federal government has supported some industry-specific efforts related to industry R&D. For example, SEMATECH and the STARnet program have supported advanced R&D in the semiconductor industry.[102] The latter program funds a number of university research centers focused on advanced semiconductor research, leveraging industry and government funds to do so.

There are a number of factors wherein the U.S. position is trending down, especially in relation to other national innovation systems. These include funding support for universities and federal labs and other innovation inputs. There is also a turn to "neo-Ludditism" in America as many public interest groups, journalists, and elites adopt an anti-innovation attitude, whether it relates to genetically modified organisms, the use of data, or automation.

Moreover, a continuing challenge for the United States remains transforming scientific discoveries and inventions made at U.S. universities, national laboratories, and corporate research labs into products that are commercialized and manufactured at scale in the United States. Table 3 provides a SWOT assessment of America's science and technology system.

Table 3: SWOT Assessment of The United States' S&T System

Strengths	Weaknesses
▪ Strong entrepreneurial system ▪ Strong corporate managerial practices ▪ S&T capabilities built upon 60 years of global leadership ▪ Leading research universities ▪ High productivity and ICT use in most sectors. ▪ Strengths in software ▪ Attractive location for high-skill immigrants ▪ Relatively strong industry-university links and tech-transfer from universities to industry ▪ Relatively strong national government that can invest in R&D and preempt state government actions that lead to market fragmentation ▪ A commitment to high levels of defense spending, much of which goes to innovation	▪ Weak tax incentives for innovation and investment ▪ Relatively low levels of domestic STEM talent production ▪ Lack of national S&T strategy and aversion to anything that smacks of "industrial policy" ▪ Declining government S&T funding
▪ Innovation in cutting-edge ICT areas such as data, artificial intelligence, and Internet of Things ▪ More robust trade enforcement policies could significantly change equation regarding trade balances in high-tech industries	▪ Continued fiscal pressures at federal and state levels will reduce funding for innovation policies ▪ Corporate short-termism reduces S&T investments ▪ Growing anti-technology attitudes in the U.S. political economy ▪ Growing foreign "innovation mercantilist" policies and programs ▪ Growing global isolation of the United States
Opportunities	**Threats**

In 2013, the United States accounted for 9 percent ($144 billion) of the world's exports of ICT goods and 8.7 percent ($33 billion) of the world's ICT services exports.[103] The United States' ICT sector value-added accounted for 7.6 percent of U.S. GDP in 2013.[104]

The U.S. government's investments in research into and early procurement of information and communications technologies has played a catalytic role in launching and sustaining the global ICT revolution. In fact, as ITIF wrote in *Federally Supported Innovations: 22 Examples of Major Technology Advances that Stem from Federal Research*, the combination of federal R&D and defense-based procurement played an instrumental role in the development of a number of early ICTs, including integrated circuits (ICs), semiconductors, databases, and supercomputers.[105]

U.S. federal government investment in ICT R&D in 2014 totaled $11.1 billion, representing 0.069 percent of U.S. GDP.[106] The Networking and Information Technology Research and Development Program (NITRD) serves as America's lead funder of R&D focused on cutting-edge information technologies. NITRD's mission is to coordinate with disparate federal agencies to efficiently use federal R&D dollars to facilitate breakthroughs in advanced IT fields, including high-performance computing (HPC), networking, cybersecurity, and software.[107] In FY 2014, NITRD received $3.97 billion in federal funding, with 27 percent of the budget supporting R&D in high-performance computing, 22 percent in human computer interaction and information management, and 20 percent in cybersecurity.[108]

The U.S. National Science Foundation also invests in information technology and computing systems research through its Computer and Information Science and Engineering (CISE) Directorate. In FY 2013, CISE invested $865 million in research activities, with $211 million directed toward advanced cyberinfrastructure, $212 million to computer and network systems, $179 million to computing and communications foundations, $176 million to information and intelligent systems, and $85 million to information technology research.[109]

The United States has never developed an explicit national ICT strategy. However, in March 2010, the Federal Communications Commission (FCC) released *Connecting America: The National Broadband Plan*.[110] The plan set an ambitious goal of providing at least 100 million homes with affordable access to actual download speeds of at least 100 Mbps and actual upload speeds of at least 50 Mbps by 2020. It also recommended the FCC make 500 MHz of spectrum newly available for broadband use by 2020.[111] However, for the most part, the plan has not been used to guide specific policy measures.

In 2013, government procurement of ICT goods and services (at all levels) totaled $178 billion, accounting for 14 percent of the $1.2 trillion spent in the U.S. ICT marketplace. Total U.S. government spending on ICT as a percentage of GDP equaled 1.1 percent in 2013. However, the United States also scored below average in its peer group in government ICT use and efficiency: 11th overall out of the 193 countries in the 2018 *United Nations E-Government Development Index*.

The U.S. federal government has launched a number of initiatives to spur development of specific ICT technologies over the years. SEMATECH is a not-for-profit consortium that performs research and development to advance chip manufacturing. Originally launched in 1987 in partnership with the U.S. government as a nonprofit consortium with the mission to address the high costs of R&D and to improve the competitiveness of the U.S. semiconductor industry, over time, SEMATECH has evolved into an international collaborative R&D institution serving the entire nanoelectronics value chain.[112]

More recently launched was STARnet, a joint program operated by Defense Advanced Research Projects Agency (DARPA) and the U.S. semiconductor industry that funds early-stage research at leading U.S. research universities. STARnet encourages a large, multi-university research community to look beyond current evolutionary directions to make discoveries that drive technology innovation beyond what can be imagined for semiconductor electronics today.[113] Similarly, in 2018, DARPA launched the Joint University Microelectronics Program (JUMP). JUMP consists of a half-dozen university-based research centers, each dedicated to a different technology theme and collectively supporting fundamental microelectronics research with a goal of catalyzing innovations enhancing the performance, efficiency, and overall capabilities of broad classes of electronics systems for both commercial and military applications. DARPA expects funding for the five-year effort to exceed $150 million, with DARPA providing 40 percent of that funding and consortium partners collectively contributing 60 percent.[114]

In July 2015, the White House announced the National Strategic Computing Initiative (NSCI), an effort to create a cohesive, multi-agency strategic vision and federal investment strategy in high-performance computing. The NSCI is envisioned as a collaboration between government, industry, and academia to develop computer systems with the processing capability and storage capacity to solve computational problems that are beyond the capability of existing systems.[115] In 2018, Congress passed the National Quantum Initiative Act that calls for making significant investments in U.S. quantum computing leadership. The act directs federal agencies to invest more in quantum computing R&D and increase funding for quantum computing education and training. The legislation would allocate $1.275 billion to quantum information science R&D over the next five years—with $125 million annually to support up to five competitively awarded National Quantum Information Science Research Centers—plus funding to create a National Quantum Coordination Office that would be responsible for developing a national quantum computing strategy.[116]

America's Manufacturing USA innovation network (formally called the National Network for Manufacturing Innovation (NNMI)) includes several Institutes of Manufacturing Innovation that touch on ICT-related issues, notably the Digital Manufacturing and Design Innovation Institute (DMDII), which assists U.S. manufacturers in applying digital manufacturing and design technologies; the Clean Energy Smart Manufacturing Innovation Institute (CESMI), which promotes the use of smart manufacturing techniques for more energy-efficient manufacturing practices; the Power America Institute, which focuses on innovation in wide-bandgap semiconductors; and America Makes, which focuses on additive manufacturing (i.e., 3D printing).[117] In October 2018, the Trump administration released a new report, *Strategy for American Leadership in Advanced Manufacturing*, which affirmed smart and digital manufacturing as one of its key focus areas, noting, "The emergence of widespread, high-speed information and communications technologies provides the opportunity to capture tremendous new productivity gains, but only if information technology can be properly integrated and leveraged with operational technology (OT)."[118]

President Obama launched the Open Government Directive in 2009, shortly after the launch of the country's national data portal, to require government agencies to improve the quality of government information and publish their agencies' information online.[119] Then, in 2013, President Obama issued an executive order requiring government data to be made open and machine-readable by default.[120] Subsequent guidance from the administration, defining requirements for usability, licensing, timeliness, and quality, has enabled the United States to become a world leader in open data.[121] The United States is a signatory of the G8 Open Data Charter and a founding member of the Open Government Data Partnership.[122] ITIF's Center for Data Innovation ranked the United States second in the G8, tied with Canada, in fulfilling its commitments to the G8 Open Data Charter.[123] In January 2019, President Trump signed the OPEN Government Data Act that requires the federal government to make government data available to the public in a nonproprietary and machine-readable format by default. In addition, it requires federal agencies to designate chief data officers and establishes a Chief Data Officer Council to promote best practices for data management across the federal government.

The Obama administration launched a Smart Cities Initiative in September 2015, committing $160 million in funding ($105 million in new spending as well as reprogrammed funds) supporting a wide array of Internet of Things applications, including, but not limited to, smart cities. The Smart Cities Initiative includes support for a range of programs including the National Institute of Standards and Technology's (NIST) Global City Teams Challenge, which encourages the development of smart city applications and Internet-connected vehicle pilots, and the establishment of Internet of Things research test beds. The federal government's Networking and Information Technology Research and Development Program also released its Smart Cities and Connected Communities Framework—a guide to coordinating federal agency investment and collaboration for smart city technology. And in December 2015, the Department of Transportation launched the Smart City Challenge, which awarded $40 million in March 2016 to Columbus, Ohio, to implement connected technologies to reduce congestion, improve transportation safety, protect the environment, and support economic growth.

To date, the Trump administration has launched few new major initiatives related to ICT. It has announced the need for additional support for AI research, and DARPA has recently announced a $2 billion AI R&D initiative.[124] And, as noted, the Trump administration recently announced increased funding for quantum computing research, and Congress is considering quantum-computing support legislation.[125]

Finally, although the United States has a strong tertiary computer science education system, its primary and secondary education systems are wanting. In 2014, only 18 percent of U.S. high schools offered rigorous computer usage or computer science classes, and many curricula focus on instilling basic literacy instead of teaching ICT-based principles and problem-solving skills.[126] A current push in the United States, led by nonprofits such as code.org, has placed more focus on computer science education in the United States. Some progress has been made, with enrollment in computer science advanced placement (AP) courses up by 85 percent since 2010 after being stagnant for much of the 1990s and 2000s.[127] Importantly, this increase seems to have been prompted by 25 U.S. states passing reforms allowing computer science to count as a math or science course—whereas just a few years ago all states counted computer science as an elective. By 2018, the number of U.S. high schools teaching computer science had almost doubled to 34 percent.[128]

The European Union

While risky to generalize over 28 member states, it is clear Europe has a number of strengths in science and technology. In particular, overall, the EU is blessed with strong engineering capabilities, which is reflected in strong industries in areas such as chemicals, automobiles, and equipment, among others. And while the overall research university system is not as strong as in the United States, it is still extremely strong globally. In addition, both at the EU and the member-state level, there are a wide array of well-conceived and strong innovation policies and programs that help EU enterprises innovate and gain global market share.

At the same time, Europe faces several weaknesses. A key one is lower levels of entrepreneurial risk-taking, and the ecosystem (e.g., venture capital) that accompanies it. In fact, from 1995 to 2010, the United States invested $321 billion more in venture capital in young, innovative entrepreneurial companies than EU nations did, with the United States investing $478.4 billion, versus the EU's $157.2.[129] Similarly, according to survey data from the Euro Flash Barometer, approximately 41 percent of Americans and 24 percent of Chinese strongly agree that in general they are willing to take risks, compared with 8 percent in Spain and 10 percent in Germany.[130] This is likely improving as the younger generation of Europeans sees entrepreneurship and risk-taking as positive, although it is still a relative weakness. And of course, the relatively less-integrated EU market holds back innovation, given that innovation industries are characterized by high fixed costs (e.g., R&D) and benefit from large markets.

Europe also has a much larger share of small firms than the United States, which limits innovation, investment, and productivity. In particular, Italy, Greece, and other Mediterranean countries stand out as having an unusually high proportion of their employment in small firms. In Europe, the economies with the highest productivity—Germany, Switzerland, and the United Kingdom—employ the smallest proportion of workers in small firms and have some of the highest labor productivity rates.[131] On the other hand, the countries in Europe with the lowest productivity (such as Greece) often have the highest percentage of small firms (e.g., two-thirds of Greek firms have under 20 workers).[132] 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.[133]

In addition, while the management quality of EU firms is strong, Bloom, Sadun, and van Reenen discovered 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 from 1995 to 2005 to this "organizational capital."[134] 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 found that American management quality was better overall than European management across a range of management quality indicators.[135] These indicators show up in sourcing decisions as well: Outsourcing by U.S. firms is more likely to be driven by transformative strategies such as reengineering processes, gaining access to new technology, and developing new analytical capabilities, whereas in Europe, the primary concern is straightforward cost-cutting.[136] 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."[137]

Europe has made significant efforts to grow ICT firms and spur ICT adoption, yet many of the EU's policies over the last decade can be characterized as defensive.

When it comes to ICT policy, Europe has made significant efforts to grow ICT firms and spur ICT adoption, at the Commission level and in many member states, including through the EU's recent Digital Single Market (DSM) initiative and the provision of considerable funding for digitally related R&D and skills training.

Many of the EU digital policies of the last decade can be characterized as foundational. Foundational policy activities are focused on addressing potential harms from ICT or ICT companies. While addressing real challenges, these policies do not do as much to spur wider and deeper digital adoption as do more proactive policies, many of which are proposed or adopted, such as regulating platforms; privacy rules such as the General Data Protection Regulation (although as discussed below components of that have been "field clearing" in nature); regulations of platforms and hate speech; regulating the "gig economy"; digital taxes; regulating roaming charges; geo-blocking rules; regulating video platforms as traditional audiovisual providers; providing more power to national governments to enforce consumer rights online; copyright reform; e-privacy rules; antitrust enforcement actions against technology companies; extending copyright to news links; regulating net neutrality; changes in international taxation rules regarding digital activity and firms; VAT reform; and promoting fairness and transparency for business users of online intermediation services.

Table 4: SWOT Assessment of the EU's S&T System

Strengths	Weaknesses
▪ Strong engineering capabilities/system ▪ Relatively strong corporate managerial practices ▪ S&T capabilities built upon 60 years of global leadership ▪ Relatively strong broadband and Internet adoption ▪ Specific research and development programs for many advanced ICT systems, such as quantum computing and high-performance computing	▪ Lower levels of entrepreneurial risk-taking ▪ Orientation to the precautionary principle ▪ Lack of integrated internal market ▪ Limited global leaders in ICT sectors ▪ Lack of strong EU government to both bring stronger policy coordination and invest more in S&T ▪ Lower levels of government and business R&D, including in ICT, compared with global leaders ▪ Privacy policies that make it more difficult for firms to effectively use data ▪ Large differences in ICT competitiveness and adoption between member states ▪ A large number of small firms that on average invest less in ICT
▪ Willingness to engage in public-private partnerships to drive sector-based and tech-based innovation ▪ Weakness of the United States on the global stage allows EU to emerge, including possibly by increasing defense spending on innovation ▪ Exceptionally strong industrial engineering capabilities; strong design capabilities in certain clusters	▪ Continual squeeze from U.S. and Chinese technology leaders ▪ Difficulty of EU governments to adequately respond to Chinese "innovation mercantilist" practices, including through stronger review of Chinese acquisition of EU companies
Opportunities	**Threats**

However, there is an opportunity for and an interest in more proactive digital innovation policies. This is in part because there is a growing and wide-scale interest in the CAS wave, with many in Europe rightly seeing it as an opportunity, in part to spur industrial competitiveness (through Industry 4.0). The emerging CAS wave plays more to EU strengths than the last two ICT waves—by being more closely related to cyber-physical integration—and this should spur a greater focus on how to proactively spur growth and innovation. As such, in the new CAS wave, there is likely to be a stronger political coalition of EU firms understanding that proactive and supportive policies are needed if they are to be globally competitive. Table 4 provides a SWOT assessment of Europe's science and technology system.

Key Strategic Issues for the EU

Europe should do two key things: focus on the industries and technologies of the future, not the recent past, and build on existing core competencies.

While technological evolution is at some level inexorable, this does not mean it will benefit all nations and regions the same or that nations and regions can afford to not put in place the most effective innovation policies to support and capitalize on emerging technologies. As such, as Europe considers how it wants to fully capitalize on the innovations emerging from the coming CAS transformation, it needs to consider several strategic factors.

Focus on the Future, Not on the Past

The first consideration is European policymakers and firms should recognize that Europe has missed many of the opportunities from the last ICT waves, including in personal computers, smartphones, cloud computing, Internet search, and social media. Because of the enormous economies of scale and scope, and first-mover advantages leading firms have in these technology areas, it will be extremely difficult for Europe to break into these industries in a serious way. It is unlikely Europe can win in these areas. While search, social media, e-commerce, smartphones, and other related areas will continue to evolve, their industry structure is already largely established. If there is a challenge to them, it will come from companies embracing CAS technologies (such as AI). To be sure, China was able break into these industries, but only through aggressive mercantilist policies that essentially shut U.S. firms out of the market, coercing the transfer of foreign firms' intellectual property, and massively subsidizing China's national champions. This is something Europe would rightly never do.

So rather than fight a rearguard action to erect roadblocks in front of U.S. technology firms while attempting to protect and subsidize EU firms, Europe should instead do two key things: focus on the industries and technologies of the future, not the recent past, and build on existing core competencies. Regarding the first, Europe needs to, as hockey star Wayne Gretzky famously said, "skate to where the puck will be." The emergence of new information technology eras has, to date, led to different firms and regions/nations gaining competitive advantage. This trend could very well continue. In other words, the winners in the CAS system (e.g., robotics, autonomous systems, blockchain, quantum computing, artificial intelligence, 5G, Internet of Things, etc.) are not predetermined, and current competitive advantage does not assure future advantage any more than IBM's leadership did not translate into the PC era, and Microsoft's leadership in PCs did not translate into leadership in search and social media. As such, Europe should focus on winning global market share in the emerging CAS technology areas and not worry about the fact that it did not fully capture the last several ICT waves.

Focus on Areas of Competitive Advantage

The second imperative is to focus on areas of existing competitive advantage. Previous digital technology waves were largely about "bits." The next wave will be increasingly about "bits and atoms." In other words, the next technology system increasingly combines digital technologies with physical things and activities (e.g., smart agriculture, smart cities, smart grids, smart manufacturing, autonomous vehicles, etc.). This plays well to Europe's considerable strengths in engineering, provided, however, Europe improves and expands its software capabilities—an area of comparative weakness—especially vis-à-vis the United States. Again, rather than bemoan the fact that there is no European search engine, European leaders should be excited that Europe could win in cyber-physical systems. But this means Industry 4.0 should be defined quite broadly. The digital transformation of atom-based industries is much broader than just manufacturing. All physical systems, including agriculture, logistics, and transportation, are being digitized—and are all areas wherein Europe has real strengths.

The other area of strength and opportunity for Europe is technology-enabled business services, including in accounting and finance, engineering services, supply chain and logistics, environmental compliance, consulting, graphics design, and biometrics. Moreover, this is an area wherein East Asian capabilities are much less developed, although India has some strengths. China is barely a player, and South Korea and Japan are weak. And Europe can build on EU and national government policy innovation in areas such as health IT and genetic records, e-government services, digital IDs, and fintech.

Address Unequal Adoption of Digital Tools Between Firms, Industries, and Nations

If Europe is to fully succeed in the CAS era, it needs to successfully address three key gaps. The first is too many EU organizations lag behind in adoption of past and current waves of ICT. There is a considerable gap between leading firms and "zombie firms" (firms with low productivity growth and limited ICT adoption).[138] And Europe has a much larger share of employment in small, relatively low-productivity, low-ICT-using firms supported by public policies that provide incentives to not get big—as getting big brings with it a host of additional regulatory and tax obligations.[139]

In addition, the gaps are not just between firms, but industries, as ICT adoption is less even between European industries. One measure of this is the standard deviation of measurement of ICT capital services as a share of labor in different industries. In Europe, this is higher (0.14) than in the United States (0.09), suggesting even less ICT adoption across industries.[140] This may be one reason why a recent National Bureau of Economic Research working paper shows the regional dispersion of productivity across firms in the EU 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 was higher in Europe than in the United States.[141] This is also why a recent study comparing the productivity of firms across the 28 EU nations and the United States found that "the dispersion in the EU is about twice as large, a finding consistent with the view that the EU economy is far from being highly integrated. Our calculations suggest that by reducing the EU dispersion to the level of the United States would increase EU productivity (GDP) by more than 30 percent."[142]

The third gap is between nations. Some EU nations, such as the Nordic nations, are on par with, or even ahead of, the United States in digital innovation. 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.[143] The difference is even higher (eight times) for cloud computing between the leading nation (Finland) and the laggard (Bulgaria).[144] The adoption rate of ecommerce orders by enterprises varies from just 8 percent in Romania to 33 percent in Norway.[145] In 2016, more than 40 percent of enterprises in Finland, Sweden, and Demark used cloud computing, while fewer than 10 percent in Greece, Latvia, Poland, Romania, and Bulgaria did.[146] In 2017, on the *European Digital Economy and Society Index*, Germany led with a score of 70, while Romania had a score of just 32.[147] Europe needs to do more to bring lagging nations up on ICT adoption and use.

Shift the Strategic Focus of the EU's Digital Policies

There are three principal types of digital economy policies: foundational, field clearing, and proactive. Foundational policy activities are focused on addressing potential harms from ICT, ICT companies, or individuals. Field-clearing policies are focused on both clearing barriers and limiting future barriers to digital innovation. Proactive policies seek not just to enable open markets and new digital entrants to compete, but to actively support digital transformation. While European nations and the EU have taken steps in all three areas, much of the focus, as discussed above, has been on foundational policies and relatively less on field-clearing and proactive policies.

While well-intentioned and addressing what many perceive as real challenges, going forward additional foundational policies will not help the EU build on its real advantages to take full advantage of the next big innovation wave. Moreover, where they make it harder or more expensive for digital innovators to operate, they can actually hold back EU digital transformation. The reality is that Europe cannot win focusing principally on foundational approaches. One reason is that at least some of the motivation for these policies comes from "analogue" incumbents seeking protection against digital competitors, including from foreign digital firms. Much of this comes in the form of claims that digital players are competing unfairly, and that Europe must "level the playing field." But policies stemming from these demands will only slow digital transformation, including in the EU nations that are already digital leaders, in part because it reduces the competitive pressures forcing old economy firms to transform through digital technologies while at the same time hamstringing digital innovators. If European policymakers want to level the playing field they should do so by reducing or reforming regulations for analogue firms, not increasing them for digital entrants, often in ways that are not required to protect consumer interests. New entrants, either from outside the EU or from EU start-ups, should be welcomed to help fully digitalize the EU economy. In fact, the competitive challenge from foreign digital players provides an opportunity for Europe to embrace competition to either disrupt analogue incumbents or spur them to engage in their own digital transformation. As such, the focus should be on examining the extent to which existing regulations designed for the analogue era are in fact appropriate for a digital world, as they otherwise hold back digital transformation. And erecting roadblocks in front of digital firms, many of whom are U.S., will inevitably mean roadblocks hampering EU digital firms. More EU firms need to embrace CAS to become "digital-first" firms. The odds of this happening are diminished when EU incumbents face fewer pressures to do the hard work of transforming themselves to become digital-first firms.

It is proactive digital policies that represent the next big opportunity for EU digital policy.

European policymakers should also consider that some components of a foundational approach reduce the attractiveness of the EU as a destination for foreign ICT investment. To be sure, American digital firms have invested in Europe mainly to gain access to markets and talent, but also, to some extent, to gain goodwill from European governments—showing them they have not only sought access to European markets but also have been contributing directly to the European economy through investment and jobs. But many now realize this considerable investment bought them almost no goodwill, and as such they are more likely to make future globally mobile investments in more-welcoming regions. Thus, there are two key issue for future EU digital policy: Will Europe continue to focus on fighting for "digital independence" from foreign (e.g., U.S.) digital firms, and will it focus largely on shaping and regulating markets, rather than on enabling and supporting disruptive innovation?

The Commission has also taken field-clearing actions, including efforts to ban data localization; harmonize spectrum policies and allocation across nations; establish more transparency in cross-border package pricing and delivery; modernize the European Electronic Communications Code for broadband investment; and establish a single digital gateway for permits. The establishment of a unified privacy framework across the EU, through the GDPR, is another example of a field-clearing policy that gives business more certainty. But there is more to do here, especially in creating a truly European market for services and ensuring emerging digital business models face the right regulatory regime, not necessarily the one applying to analogue competitors.

However, it is proactive digital policies that represent the next big opportunity for EU digital policy. These include policies to help expand and improve the resources firms rely on for success, including ICT R&D, data, broadband networks, and digital skills. Digital skills are particularly important, as Europe lags behind the United States in the share of the workforce with software skills, which is perhaps the key ingredient for digital economy success. But proactive policies, often implemented through public-private partnerships, also support digital innovation and adoption in key technology areas, such as digital IDs, high-performance computing, AI, and key industry applications such as health IT, smart grids, and smart cities.

Build on Europe's Unique Advantages

While Europe lags behind the United States and China in several areas related to the digital economy, it has several unique advantages, particularly over the United States. To win in the next CAS wave, Europe needs to double down on these advantages. There are two that deserve particular focus. First, unlike the United States, Europe is more open to supporting proactive policies to help drive digital transformation in particular areas, such as the smart grid, smart cities, health IT, E-IDs, etc. In contrast, the United States remains constrained by an ideology which holds that the free market best addresses such issues, and government intervention only retards innovation. This is clearly not the case with many emerging technologies that face a host of market failures, including public-goods issues, high levels of risk and uncertainty, externalities, and collective action problems. Smart government policies can accelerate digital adoption and transformation where these market failures are rampant, enabling EU firms to gain what hopefully could be a sustainable advantage. For example, one factor holding back robust adoption of health IT systems in the United States is few health care providers have such systems, so few patients have personal health records, thus reducing both the pressure on health care providers to become digital and the incentives for third-party companies to develop and sell digital health systems to patients. Some EU nations, particularly those in Scandinavia, have worked to break this "chicken-or-egg" conundrum.[148]

The second opportunity is to take advantage of the "laboratories of democracy" Europe enjoys, particularly in many of the smaller nations. The notion of laboratories of democracy—a term coined in 1932 by U.S. Supreme Court Justice Louis Brandeis—refers to the role U.S. state governments play in developing and piloting new policy approaches that are sometimes adopted nationally. National digital advantage in many technology and application areas depends both on coordination of multiple actors (a task that can be extremely difficult in large nations such as the United States, or even France or Germany) and policy innovation. But Europe has numerous smaller states that have shown a willingness and ability to be more innovative and flexible. The Commission should double down on these innovations, seeking to spur more bottom-up policy innovation, and then to bring the innovations fully to market, diffusing them throughout all of the EU. The Commission needs to seed more experiments across the EU and then help those experiments scale and be adopted in an interoperable way by all 28 member states.

Win Through Out-Investing the United States

One reason for America's lead in ICT is significant public investment, including through the Department of Defense, NASA, and the National Science Foundation. Indeed, in the early 1960s, the United States government invested more in R&D than all other governments and all non-U.S. businesses combined. But that advantage has shrunk and in many cases reversed itself. Federal funding for R&D in FY 2017 as a share of GDP was the lowest it had been since the Russians launched Sputnik, almost 60 years ago.[149] And to restore the federal R&D to GDP ratio to levels averaged in the 1980s, the federal investment had to increase by more than 90 percent.[150] This is why the United States now ranks eighth among OECD nations in the ratio of government-funded R&D to GDP. This is highly unlikely to get better, and because of the massive U.S. budget deficit and national debt, and the nature of U.S. domestic politics, it is likely get worse.

This should provide Europe with a real opportunity to gain ground on the United States through smart public investment, particularly in R&D related to CAS technologies. To be sure, the Commission has announced plans to do this, but these plans need to be followed through on and even significantly expanded. Only five nations exceed the United States government's investment in R&D as a share of GDP (0.70 percent in 2015): Austria (0.99); Denmark (0.87); Finland (0.84); France (0.79); and Germany (0.81). Overall, the EU-28 nations invest 0.62 percent of GDP in government R&D, which equals 88 percent of U.S. levels. The Commission should set a target to exceed the U.S. level by 20 percent by 2025. This would require an additional investment across Europe of €45 billion in 2025.

Europe will also need more effective technology-transfer and commercialization policies if it is to get more out of its investments in R&D. This is especially true when considering U.S. high-tech firms gain over two-and-a-half times more productivity than European high-tech firms from the same level of R&D investment. Indeed, businesses in the EU lag behind U.S. businesses not just in the amount they invest in R&D, but also in their ability to transform these investments into productivity gains. That was the finding of study by four European economists, which found that between 2004 and 2012, U.S. businesses realized nearly three-times more productivity growth than EU businesses, for a 1 percent increase in business R&D investment.[151]

Because high-tech firms spearhead economic growth, it should be of even more concern that when the economists isolated only high-tech firms, those in the EU also lagged significantly behind those in the United States when it came to their innovation capabilities. The authors estimate that a 1 percent increase in R&D investment would give U.S. high-tech firms 2.5 times more productivity growth than EU high-tech firms.

In summary, the global competition to succeed in CAS development and adoption is intense. More regions and nations are currently competing than during the last two digital innovation waves, and the level of competitive intensity between nations has increased. This leads to a key question for Europe: To what degree does Europe want CAS transformation, which, if successful, will include not only more "technology firms and jobs" but also more disruption and the replacement of existing firms and business models with new digital ones? If Europe wants to win, it needs to raise its ambitions and the urgency with which it seeks to attain them. It has to do more than just the "easy" things of supporting more broadband or improving digital skills or announcing a new Horizon 2020 program, as important as those activities are. It needs to aggressively break down barriers to CAS transformation while at the same time supporting the digital transformation of whole industries.

POLICIES FOR CAS TRANSITION

Competitive advantage in advanced-technology industries generally, and CAS technologies and industries specifically, as well as rates of CAS adoption, will depend on a host of factors. As David Moschella wrote in *Seeing Digital*, these factors include:

- Which nations have the most skilled programmers, engineers, and workers?
- Which have the most advanced networks and related infrastructure?
- Which generate global technology companies?
- How important and effective are various industrial policies and strategies?
- Where is the national technology ecosystem doing world-class work?
- Are government IT policies mostly effective or counterproductive?
- Is a nation within the Anglosphere or Sinosphere, or on a different path?

If Europe is to succeed in the CAS transformation, it will particularly need to make ICT-enabled productivity growth—rather than vague social missions organized around the amorphous concept of "grand challenges"—a top priority.

Why Does Europe Need a Stronger and More Comprehensive Digital Policy?

There are several reasons why Europe needs to not only continue, but deepen its digital policy efforts. The first is Europe is in competition with other regions that are making digital development and adoption a centerpiece of their policies, and failure to respond means challenges for Europe's digital competitiveness. The second is there are a host of regulatory issues that shape digital transformation, including product and labor market regulations that can limit or slow down digital transformation. The third is firms rely on resources that governments can help produce, such as research and a skilled workforce.

Fourth, many industries have chicken-or-egg characteristics that make digital progress difficult. For example, the development of connected vehicles would proceed faster if infrastructure were connected, and vice versa.[152] A smart electric grid would help spur Internet of Things-enabled smart appliances and the adoption of electric vehicles, and vice versa. In other industries, success depends on industry coordination. For example, digital health systems would be hampered if all parts of the health system (hospitals, payers, doctors, labs, etc.) did not all work together.

Finally, ICT and business are evolving together, which requires new management practices and new business models. This is true at the societal level as well. As CAS technologies evolve, societies need to embrace not only them but institutional innovation to enable new governance models. For example, 3D printing technology will likely make it eventually possible to physically "print" houses, but unless local zoning and building codes are reformed, innovation will be limited.

Notwithstanding this, firms in Europe will ultimately determine the EU's digital success. European firms have more capital than their counterparts outside Europe, which means they have to figure out the complex process of adopting digital technologies in ways that work economically.

However, smart government policy is needed in several main areas, including framework conditions (i.e., the right regulatory framework, appropriate competition policy, and trade policy); external organizational resources (i.e., R&D, skills, data, and broadband infrastructures); technology, industry, and firm policies; and finally, culture and organizational structures.

Given Europe's unique governance structure, these roles will differ by level of government. The EU will have a significant responsibility for framework conditions. It should also provide funding for key firm resources, particularly R&D. But perhaps one of the key roles the Commission needs to play is to more aggressively foster digital public-private partnerships in a wide array of emerging technology areas in partnership with EU nations (and to some extent subnational governments and firms).

Finally, and perhaps most importantly, if Europe is to succeed in the CAS transformation, it will need to make that transformation, and in particular ICT-enabled productivity growth, a top priority, rather than social missions organized around the amorphous concept of "grand challenges."[153] There appears to be considerable misunderstanding outside the United States of the role of grand challenges historically in driving U.S. innovation. To the extent the response to Sputnik and the space program led to commercial technology advancement and U.S. success, it had less to do with the fact that they were grand challenges per se, but rather that the needs of government spurred widespread investment in university and federal laboratory R&D, and skills development in areas that had widespread applicability to commercial technology development. This in turn led to developments and advancements in technology such as GPS, semiconductors, supercomputers, AI, and the Internet.[154]

As such, if the EU is to go down the mission-focused or grand challenge path for its innovation policy, the mission should be one that will have clear crossovers to the development of CAS and related technologies. The mission that best enables that is boosting productivity through technological innovation.[155] As a response to the natural question, "What about jobs?" it is important to mention the notion that higher rates of productivity growth come at the expense of job creation should be rejected once and for all, as the evidence, studies, and logic all show clearly that productivity and job creation are, if anything, positively correlated.[156]

Framework Conditions

At the base of digital policy lie framework conditions that affect the entire economy and all organizations, and have an impact on organizational competitiveness, innovation, and productivity. These include regulatory, tax, competition, and trade policies.

Regulation

Unlike in past transitions, wherein digital technology enabled firms to grow and prosper with only some industries disrupted by new entrants, technologies, and business models (e.g., travel agents, newspapers, etc.), the coming CAS transformation will likely bring more widespread disruption. The last two transitions were, to use Clayton Christenson's term, "more about incremental and breakthrough technologies, but less about disruptive and game-changing innovations."[157] The coming transformation is likely to be more about disruptive and game-changing technologies that will have more profound impacts on more markets, industries, and organizations. As IT expert David Moschella put it, in past digital transitions, technology firms were "arms merchants" in thatthey sold tools to whomever wanted them to improve their business or organization. Now, tech firms, incumbents, and start-ups alike are seemingly an invading army challenging a host of industries with radical disruption.[158] The disrupted are unlikely to sit back and accept their fate; they are likely to enlist government to help them—albeit framed as a narrative about protecting the public interest.

There are two key types of regulation – social (e.g., privacy) and economic (e.g., audiovisual industry rules) – that can limit or enable innovation. At the same time, there are two overarching orientations to regulation: the precautionary principle and the innovation principle. There is general agreement that Europe lies more toward the precautionary principle and the United States more toward the innovation principle. This is important because in an era when leadership in CAS technologies will be shaped more than in the past by whoever gains first-mover advantage, regions that enable innovators with the most effective environments and supports to get to market at scale first will often win, even if the other regions' regulatory systems provides more protection. Indeed, as more industries are being transformed by digital technologies, there are considerable advantages to being first movers, including network and lock-in effects and moving down both the learning curve and scale economies curve to create sustainable advantages over followers.

A case in point is artificial intelligence. Regions with the most-welcoming and least-restrictive views toward AI will likely be the ones that produce the most-competitive firms. Yet, some in Europe and, increasingly, the United States seem to have decidedly mixed views of AI. Some advocates and advocacy organizations seek to limit AI and CAS development overall on the grounds of protecting privacy, fairness, jobs, and other social values. While there are valid concerns that AI can be used in ways that are harmful, there is little reason to believe market forces, combined with the appropriate light-touch regulation, would not minimize harms and maximize benefits.[159]

A second form of resistance to CAS will come from professions and industries threatened with economic disruption. Such resistance is logical, even if it is against the public interest. But it is the source of much resistance to lowering product market regulation that limits digital transformation in Europe. As an OECD report noted, "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."[160] Likewise, MIT economist Phillipe Aghion and colleagues found that liberalizing product markets is key to enhancing productivity growth in developed economies.[161] London School of Economics economist John van Reenen and colleagues 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."[162] Overall, they found that product market regulations act as a productivity drag on ICT, lowering its impact by 16 percent for each dollar invested.[163]

The evidence suggests that relative to the United States (and likely China), product market regulatory burdens are higher in Europe. Cette, et al. examined product market regulation in six industries (energy, transport, communications, retail distribution, banking services, and professional services). They found that while the undue regulatory burden is lower in the United Kingdom, the Netherlands, and Sweden than the United States, it is higher in Germany, Denmark, Spain, the Czech Republic, France, Finland, Italy, and Austria.[164] When they estimated the negative effect of product market regulation on ICT capital investment, only the United Kingdom was lower than the United States, with Italy the highest. And that in turn lowers potential multifactor productivity growth in the most-regulated EU economies by between 0.4 and 1 percent a year.[165] This may be why the McKinsey Global Institute estimated that, overall, Europe operates at only 12 percent of digital potential, in comparison with 18 percent for the United States.[166]

One of the key objectives the Commission needs to focus on is more aggressively fostering digital public-private partnerships in a wide array of emerging technology areas.

This is why efforts to level the playing field between traditional firms and digital innovators is all too often an effort by incumbents to hobble competitors. So, when the EU stated, "The government believes it is important to have a fair economy and a level playing field between traditional and new players, where new players cannot escape the rules," the result can risk protection for incumbents at the expense of consumers and more-competitive EU digital firms.[167] In fact, seeking a level playing field risks subjecting a wide array of ICT services and applications to increased regulation that would risk raising costs or lowering quality.

As such, in efforts to level the playing field, the EU should be focused more on equivalent protection, not equivalent regulation. In other words, the goal should not be to subject new digital business models (such as "over-the-top" video or voice services) to the same regulation as incumbents—something that will often limit innovation. It should be to ensure regulation of new business models provides the same levels of protection, even if the regulatory requirements themselves differ.

The Commission also should actively support national efforts to reform and improve regulation. One example is the Netherland's "Better Regulation and Services" program, which aims to remove obstacles to innovation and create scope for experimentation. Nations should be encouraged to focus on regulatory experiments and "sandboxes," including in relation to statutory provisions on experimentation, in which governments experiment with more flexible regulations in a controlled setting.

Where Europe really needs a level regulatory playing field is with regard to differences between regulation of traded-sector industries across the region. To do that t**he Commission should preempt digital regulations that individual member states adopt. A core tool to enable a Digital Single Market is regulatory harmonization.** To that end, the Commission has proposed to enact floors below which member states would not able to go. But the Commission appears not to be seeking a ceiling above which member states also could not go. For example, according to Article 8 of Directive 99/44/EC on consumer sales, member states can use more stringent provisions in the field covered by the directive. If the goal is to ensure a baseline level of consumer protection, then setting an EU floor and allowing member states to institute more stringent regulations will help. But if the goal is a Digital Single Market that makes it easier for digital producers in Europe to sell across borders, then the EU needs to also set a ceiling and a floor that are the same. In other words, it should not let national governments set their own more-stringent standards. Multiple and conflicting standards go against the goal of achieving a Digital Single Market.

In order to ensure a more innovation-focused approach to regulation, the Commission should make sure the EU's Regulatory Scrutiny Board focuses more systemically on innovation impacts from proposed regulations. Too often regulatory review bodies focus on short-term static effects—e.g., whether it will raise costs—and less on how the regulation's impact (positive or negative) will affect longer-term, dynamic effects (e.g., innovation). **The Commission should create within the Regulatory Scrutiny Board (RSB) an Office of Innovation Review whose mission would be to serve as an "innovation champion" in the regulatory process.** Such an office would have authority to push agencies to either affirmatively promote innovation or achieve a particular regulatory objective in a manner least harmful to innovation.[168] At the same time, when the Commission is proposing regulations that would clearly move digital innovation forward (such as mandating the free flow of data within the EU) the RSB should not require an assessment of employment impacts, as doing so essentially penalizes regulations that lead to higher productivity.[169] At a minimum, if employment impacts are measured, the RSB should also assess expected productivity and wage gains.[170]

Moreover, when drafting regulations, Commission directorates need to pay more attention to innovation. For example, although the Commission staff working document,"Better Regulation Guidelines" is 90 pages in length, it gives little attention to the need to and process for evaluating innovation impacts, other than one line that asks, "Have potential impacts on innovation been considered?"[171]

In addition, **the Commission and member states should continue with efforts to develop regulatory sandboxes,** which are frameworks that enable fintechs and other innovative entities to work with regulators to test their innovative products, services, and business models with real consumers, in a controlled environment, on a trial basis. In

March 2018, the Commission released an action plan to develop best practices for regulatory sandboxes based on guidance from European supervisory authorities.[172] Similarly, the European Banking Authority (EBA) released a roadmap for fintechs, with guidance for regulatory sandboxes released in December 2018.[173] These efforts are important to create a flexible regulatory framework that enables experimentation in financial services.

The Commission should also consider more formalized approaches to help member state regulators learn from each other around best practices in regulating emerging CAS technologies. Identifying the best and most innovation-friendly way to craft regulations for blockchain or drones, for example, is an extremely complex undertaking. Member states should be able to more easily learn from each other.

Finally, and most fundamentally, Europe needs to make a core decision about whether it sees innovation generally—and CAS transformation specifically—as a fundamentally progressive force that should be supported and encouraged, or as something uncertain, with all sorts of possible downsides. All things being equal, nations that embrace the former view will outpace nations that are more cautious and suspect.

AI and Regulation

Success in the CAS economy requires a "Goldilocks" approach to regulation: not too strong and not too weak. Getting this balance right is important for several reasons. One is ensuring user trust in the technologies. For example, consumers and companies will want to be assured that artificial intelligence algorithms are not biased, and the personal data they share with companies is not abused. A second reason is to enable innovation and ensure regulation does not unduly hamstring companies from developing robust technologies and market offerings.

This is particularly important with AI innovation. European policymakers have recognized artificial intelligence as a key driver of economic growth, but have also adopted regulations, most notably the General Data Protection Regulation (GDPR). While the GDPR was critical to establishing a common regulatory framework across the EU—something that enables digital innovation—there are some provisions that could limit the value AI can offer the EU, depending on how it is implemented.[174]

The GDPR contains a number of provisions that could hinder the development and adoption of AI in Europe, even while providing little useful protections to Europeans.[175] For example, Articles 13–15 of the GDPR create an obligation for companies to provide either detailed explanations of individual algorithmic decisions or general information about how the algorithms make decisions.[176] However, the former would undermine the accuracy of algorithms and, perversely, lead to unfair decisions, as there is inherently a trade-off between accuracy and transparency in algorithmic decisions.[177]

Likewise, the "right to erasure" in Article 17 will also limit the use of AI. All AI systems that operate using unsupervised machine learning—those that improve themselves, without outside help, by learning from the data they process—need to "remember" all the data they used to train themselves in order to sustain rules derived from that data.[178] However, erasing data that underpins key rules in an AI system's behavior can both make it less accurate and limit its benefit to other data subjects—or even break it entirely.[179]

There are several steps European policymakers should take to address these challenges. When laws are too difficult to follow, regulators end up not enforcing the standards of behavior the laws were ostensibly written to create. If the EU is serious about building a rules-based single market with high standards, **it should consider simplifying the GDPR by reducing it to a set of easily comprehensible rules that focus on preventing consumer harm**, rather than trying to tightly control how companies manage and use data, at the expense of innovation. More broadly, the Commission should conduct a thorough review of the implementation of GDPR in 2020 to evaluate where it has worked well and where it needs improvement.

Additionally, rather than targeting AI with requirements that do not apply to human decision-making, any requirements for transparency, evidence, oversight, or explanation should be technology-neutral. The EU should ensure that an individual's right to a review or an explanation of a particular decision should depend on the nature and seriousness of the decision in question, not simply on whether the decision was made by a human or an algorithm. Applying these rights exclusively to decisions made by algorithms creates a disincentive for companies to use AI, as it represents an additional compliance cost and makes using the technology less efficient. Moreover, such a requirement would allow for unfair decisions made by humans, which tend to be more open to bias in the first place, to avoid similar levels of scrutiny and accountability. The EU should also take into consideration that different rules may be necessary for different industries, and therefore avoid general requirements.

Regulators should take a liberal interpretation of erasure and allow companies to anonymize personally identifiable data, without impairing algorithmic models. Customers' rights to erase their data should not usurp algorithms' functionality in regard to working for other customers. To that end, rather than a right to erasure, consumers should have a right to anonymity, wherein they can require companies to either delete their information in such a way that does not interfere with an algorithm's behavior or anonymize their data before any additional processing. As "anonymization" means retaining only that which is not personally identifiable, fulfilling the right to erasure through anonymization may be legally permissible within the current wording of the GDPR. Amending the GDPR to clarify this would undoubtedly help remove uncertainty.

European policymakers should identify and implement proactive nonregulatory ways to address challenges related to AI. In particular, they should devote more of their attention to facilitating the development and adoption of AI. The Commission has already taken some important steps in this direction, adopting its Communication on Artificial Intelligence in April 2018, detailing its plans to increase development and adoption, and prepare for the socioeconomic disruption AI could cause.[180] But more can be done. For example, to address common concerns about the potential for AI to be biased or discriminatory, policymakers should focus on constructive, nonregulatory approaches, such as funding research into explainable AI systems, developing shared pools of training and validation data, and sharing best practices about how to use AI responsibly. These might be some of the issues the proposed AI excellence centers will tackle. Taking these steps could help the EU maximize the value of AI and minimize its harms, without limiting innovation.

Regulatory Policies to Support Emerging Digital Technologies

The EU should enact policies to adopt key digital technologies that support its efforts to become a global leader in areas including fintech, unmanned aircraft systems (UAS), and autonomous vehicles (AVs). Broadly, these policies should include some industry support in the form of research and development, regulatory reform, and harmonization of domestic and international laws. However, there is no universal framework for innovation, and as such, Europe will need to take an industry-specific approach that is tailored to each technology.

The EU should enact policies to adopt key digital technologies that support its efforts to become a global leader in areas including fintech, unmanned aircraft systems (UAS), and autonomous vehicles (AVs).

Fintech

Fintech, a portmanteau of the words "financial technology," refers to a business that uses the latest innovations in information technology to radically improve financial services.[181] These companies are using innovative technology (e.g., artificial intelligence, blockchains, and mobile technology) and different business models (e.g., peer-to-peer networks) to increase productivity in the financial services sector and create more-convenient, higher-quality, and cheaper financial services.

Fintech promises to use technology to lower the cost of financial services and bring more people into the financial system. Robo-advisors use artificial intelligence to give access to personally tailored investment options to individuals who may not be able to afford a financial advisor. Cryptocurrencies, crowdfunding, and alternative lending are opening new markets for both lenders and borrowers to invest and gain access to capital. Blockchains offer the potential to improve the efficiency of financial instruments while lowering costs by cutting out unnecessary intermediaries. European fintechs are already attracting considerable amounts of investment. In the first half of 2018, fintechs in Europe saw an estimated €23 billion in investment, compared with €12 billion in the United States and €14 billion across Asia.[182] With the right set of policies, Europe can continue to capture investment and become the world leader in disruption within the financial services sector.

This transformation within the financial services sector, however, is not without its challenges, such as complex regulations designed for older business models, and the evolving nature of security threats. Public policies that actively support fintech innovation and carefully avoid doing harm by overly constraining new developments will position Europe to be a leader in financial services. European policymakers should take four main steps to become global leaders in fintech transformation.

First, EU member states should promote broader adoption of fintech and reduce the risks associated with new technologies and business models by becoming early adopters. The EU and member states should also provide research and development funding to tackle technological challenges associated with improving financial services. Technical financial infrastructures, such as instant-payment systems, rely on standardized technical specifications to allow independent systems to interface and work seamlessly together, which often requires cooperation between the public and private sectors.

Second, the EU should support fintech transformation through regulatory reform, ensuring regulations enable innovation to flourish, while at the same time achieving regulatory goals. To accomplish this, European policymakers should make several policy changes. For one, EU policymakers should draw clear boundaries and set priorities for regulation. For example, regulators may place a higher priority on examining rules for alternative lending than crowdfunding because of the higher risk of abuse. In addition, EU member states should work to remove duplicative regulations. European regulators should also adopt regulatory sandboxes—wherein regulators work with companies to understand how they are incorporating technological innovations into their products and test how regulations would affect these services. Moreover, to maximize the effectiveness of enforcement actions, regulatory agencies should create a system of incentives that promote desirable behavior and discourage undesirable behavior, doing so in a way that limits compliance costs.[183]

Third, the EU should seek to create international harmonization for financial services laws and regulations, especially for those affecting routing transactions, anti-money-laundering, regulatory compliance, and international access to financial data for law enforcement. A sound international framework of cooperation and coordination based on harmonization is essential to effective regulation and supervision of fintech applications, reducing systemic risks to financial stability, and ensuring innovation in financial services proceeds apace.

Finally, the EU should promote fintech cybersecurity. Financial businesses, especially banks, continue to be the target of hacking that has resulted in the exposure of millions of consumer records. Moreover, complex financial systems often lack resiliency. To ensure fintech companies are creating secure services, EU member states should create incentives for better cybersecurity in fintech products through purchasing, regulation, and oversight.

Unmanned Aircraft Systems

Unmanned aircraft systems (UAS), commonly referred to as drones, present significant opportunities for technological innovation. They are lightweight, maneuverable, and capable of carrying cameras, sensors, and other sorts of technologies into places that used to be much harder or more expensive to reach. Both the public and private sectors are using drones to improve their services.

This technology has the potential to boost productivity across a wide number of sectors, such as utility and infrastructure inspections, express shipping and delivery, geographic mapping of inaccessible terrain, disaster management and response, storm tracking, and more. For example, farmers are using UAS for precision agriculture, enabling them to improve irrigation, crop inspection, and pesticide application.

But to capture the value of many of the more futuristic UAS applications, such as package delivery, EU policymakers will need to make policy decisions that enable effective management of the technology. The policies the Commission creates for UAS will also pay dividends for next-generation autonomous aircraft, such as vertical takeoff and landing, which could revolutionize urban air travel.[184]

The EU can benefit from UAS technology by pursuing four policies that actively support its nascent drone industry. While many of these plans are already underway, getting implementation right will be important.

First, the EU should support and expand research and testing for UAS integration into the airspace. The European Aviation Safety Agency (EASA), which is in charge of air traffic safety, should focus its efforts on gathering risk data from UAS operations to incorporate into its rulemaking process. Moreover, with the integration of UAS, air traffic controllers will face a large surge in air traffic. The European Organisation for the Safety of Air Navigation (Eurocontrol) should continue its work on timely development of advanced UAS air traffic control systems.[185]

Second, the EU should establish a regulatory system that both enables permissive use of the technology and ensures reasonable safety practices. In December 2017, the EASA took steps in this direction by creating a risk-based regulatory framework that focuses on three categories of operations, and the EASA adopted specific rules for each category of operations.[186] Ideally, EASA should set a risk threshold the private sector would have to meet or exceed to operate UAS, based on the accepted level of risk for each category. This would involve EASA giving the private sector more freedom to make improvements to UAS technology when those improvements reduce the actual risk of an accident. Flexible, risk-based rules are especially important because certain types of UAS, such as micro UAS, pose significantly fewer safety risks than larger models.[187] In addition, these regulations should be technology neutral, neither favoring nor disadvantaging any one technology. Clearly, all technologies are not the same. The safety concerns associated with a 2 kilogram (kg) UAS are not the same as those associated with a 20 kg UAS—and neither bears the same level of risk as a manned helicopter. Where there are differences in technology, European policymakers should establish rules that recognize the risks distinct to each.

Finally, the EU and EASA should try to ensure UAS rules supersede duplicative and contradictory regulatory frameworks from its member states. For example, neighboring France and Belgium have different height restrictions for UAS operations.[188] Member states should be careful not to create a jumble of duplicative, contradictory, or ill-conceived policy responses that slow the deployment of drone technology, as this could unnecessarily curb adoption and inadvertently hinder legitimate uses.

Autonomous Vehicles

Autonomous vehicles (AVs) can improve public safety, advance transportation efficiency, increase autonomy for people with disabilities, and offer many other social and economic benefits. ITIF estimated that if autonomous vehicles were widely adopted, they would provide over $1 trillion annually in economic benefits to the U.S. economy, largely through reduced accidents and congestion, and to some extent, reduced energy costs.[189] It is therefore incumbent on the EU to establish a policy framework that supports the development and adoption of the technology. European policymakers should take three main steps to become global leader in AVs.

First, an effective European AV industry will only come about if policymakers work to enable development of a range of enabling technologies. To support AV integration, the EU should support research and development of these technologies, such as artificial intelligence and intelligent transportation systems (ITS). Regarding ITS, Europe's strategy should focus on vehicle-to-everything (V2X) communications infrastructure—technology that enables vehicles to communicate with each other, the roadway, and even nearby people and objects.[190] Beyond focusing on the connected vehicle, this strategy should include identifying innovative ways of using related technologies to drive high impact in larger intelligent transportation systems, such as emergency vehicle warning systems, adaptive traffic signal lights, and connected parking meters. Moreover, these systems are most effective when operated at scale—often at an international level—and must be adopted by the overall system and individual users at the same time to be most successful.[191] Therefore, policymakers should promote coordination and interoperability—the ability of different IT systems to communicate, exchange data, and cooperatively use that data—between different EU member implementations.

Second, the EU can also become a leader in AVs through regulatory reform. This can come in the form of performance-based standards around safety, tech-neutral standards for vehicles, and regulatory oversight that creates incentives for companies to protect consumers from harm.[192] Policymakers should ensure regulators have the resources necessary to monitor and understand the industry, and can make timely regulatory decisions that balance safety with innovation.[193] In addition, safety standards should be adopted uniformly across all EU member states to avoid duplicate and contradictory systems.

Finally, regarding issues related to data protection, EU policymakers should be wary of overly restricting the use of vehicle data. For example, the Commission has already adopted regulations that could reduce the effectiveness of AI, which could have spillover effects that negatively impact innovations that rely on advances in AI, such as AVs.[194] Similarly, due to privacy concerns, EU policymakers restricted the use of safety data from the EU's "eCall" regulation, which automatically requests emergency services in the event of a vehicle crash.[195] Rather than inhibit beneficial uses of data, EU regulators should create rules that allow companies to collect and use vehicle data to improve consumers' well-being.

Policymakers should focus on enforceable, transparent, self-regulatory principles for the auto industry to protect the cybersecurity and privacy of vehicle owners. Ideally, these rules would include all stakeholders, be clear and transparent, and be overseen by an independent organization to assess their effectiveness.

Competition Policy

It is beyond the scope of this report to go into detail on the relationship between competition policy and innovation. However, it is worth noting two things. First, despite technological innovation having changed the structure and function of advanced economies and in many ways, competition policy around the globe has not caught up. Second, a number of competition scholars have attempted to intellectually cope with these changes—and collectively, these scholars constitute an "innovation school" of competition policy.[196] Most of these scholars believe the focus of antitrust measures should be much more on the side of spurring firm productivity and innovation, while worrying somewhat less about allocation efficiency or distributional effects.

Regulators should recognize that because data is nonrivalrous, one company's possession of data does not have to come at the expense of another's.

These scholars also recognize the importance of dynamic markets and innovation. They see different industries as having different dynamics and therefore requiring different antitrust approaches. Proponents believe there can be many instances wherein the losses in allocation efficiency (from higher prices in less-than-fully competitive markets) will be - dwarfed by the gains in productivity and innovation. Indeed, the focus of antitrust thinking should be on the long-term trajectory of product value and price, not just on current consumer welfare measured by short-run prices.

The innovation school also focuses less on favoring competitive markets and more on examining processes that develop competitive, innovative, and productive firms—particularly firms that can effectively compete in global marketplaces. Moreover, increased concentration can be pro-innovation, even when it hurts other competitors. As U.C. Berkeley scholar and former member of President Obama's Council of Economic Advisors, Carl Shapiro wrote, "If appropriability is low, e.g., due to weak intellectual property rights and significant spillovers to rival firms who engage in imitation, then increased concentration can improve appropriability and promote innovation, weakening the link between concentration and competition."[197] As such Commission officials, particularly in Directorate-General (DG) Competition, need to engage in a robust process of research, debate, and dialogue to explore how both digitally-based innovation is changing markets such that higher levels of concentration may be consumer-welfare maximizing, and EU competition policy can more effectively support innovation in network- and innovation-based industries.

Data and Competition Policy

One aspect of competition policy that is particularly relevant to the digital economy relates to how competition regulators treat the accumulation of large sets of data. Some advocates, pundits, and small and start-up AI companies argue that in order to level the playing field, regulators should force large companies possessing considerable amounts of data to make this data openly available, usually for free. Using value-laden terms such as "open data" and arguments that somehow the possession of large amounts of data is a threat to competition, they argue such policies would release the "oil" of the data economy, now held unfairly by "digital OPECs."[198] Policymakers should reject such arguments, in part because, at least for small AI companies, they represent special pleading to get a key resource without paying.[199]

More broadly, regulators should recognize that because data is nonrivalrous, one company's possession of data does not have to come at the expense of another's. More importantly, efforts to mandate that firms share proprietary data with other companies can limit innovation by reducing incentives for EU firms to collect and analyze data, essentially turning data into an interchangeable commodity.[200]

Regulations prescribing a particular business model or specific contract language related to data ownership are likely to limit, not advance, innovation.

In a recent study economists Anja Lambrecht and Catherine Tucker found little evidence that the mere possession of even large amounts of data can protect a company from a superior product offering because data are seldom inimitable, rare, valuable, or non-substitutable.[201] One reason is having the right algorithms and business models tends to be much more important than having the right data. Another is much data has a short "half-life." Any market advantage it provides is temporary. A third is large amounts of data are often available privately to any party that wants to buy it. The key constraint is translating the data into a competitive product. Finally, data is easily transferable and nonrivalrous. Sharing it with another party does not preclude that party from sharing it with others.

One area of data policy receiving attention is business data, as increasing amounts of data are being produced or captured by machines. For example, global mining company Rio Tinto has created a "Mine of the Future" program to identify the size, location, and quality of ore by aggregating the data it collects in real time. Rio Tinto collects this data from both the trucks and the drills it uses in its mines all around the world, and processes at its Processing Excellence Centre. In manufacturing, operations are slowly becoming "intelligent," with more and more machines being sensor-based and connected, enabling real-time analytics to be run on machines and even across whole establishments.[202] One issue related to such machine data is who owns the it? For a factory, is it the manufacturer who owns the machine? Is it the machine maker who sells the machines to the manufacturer? Is it the third-party system integrator who connects a company's machines?[203]

To examine this issue, the European Commission has established a working group of experts.[204] The Commission aims: "to ensure fair and competitive markets for Internet of Things objects and for products and services that rely on nonpersonal machine-generated data created by such objects." The Commission also suggests a number of principles for companies to consider when drafting relevant contracts.

But these concerns could very well be premature. First, the norm, at least presently, is for machine buyers to own the data, at least for commercial and industrial applications. Most companies do not want the data going outside of their control. To be sure, some machine builders and system integrators have created lightweight, secure remote virtual private network (VPN) access that allows a company to access data at a manufacturing site, if the company requests it; just like a PC user can let a remote help desk access their PC to fix a problem. But like a help desk helping someone with their PC, when a remote factory task is complete, the connection is closed. There is a second reason why the business model is likely to be one in which machine owners own the data. Pushing all of the data out to a third party increases the threat of hacking as compared with just one company holding it. It is sometimes impractical because of the large quantity of data involved. Some machines, of which there can be thousands inside a factory, have I/O backplanes that operate at 1 GB per second.

Moreover, there are good reasons to believe market forces will ensure fair data relationships. In few industries do machine sellers have a monopoly, and therefore they have an incentive to provide the kinds of products and services customers want. Moreover, bad publicity from "unfair" data practices can be real and something most companies seek to avoid. We see this dynamic in the agricultural sector, regarding concerns by U.S. farmers that big agricultural firms, such as John Deere, would control data from precision and smart agricultural systems. However, working with farm organizations in 2014, a number of large agricultural companies, including John Deere, signed on to a set of data principles, including one on ownership:

Underlying and helping to shape CAS development and competitiveness is the nature and evolution of the global trading system.

> We believe farmers own information generated on their farming operations. However, it is the responsibility of the farmer to agree upon data use and sharing with the other stakeholders with an economic interest, such as the tenant, landowner, cooperative, owner of the precision agriculture system hardware, and/or ATP [agricultural technology provider] etc. The farmer contracting with the ATP is responsible for ensuring that only the data they own or have permission to use is included in the account with the ATP.[205]

But even with these technology and market forces keeping the data in the hands of the machine owners, there may be cases wherein machine sellers have a business model that involves the collection and aggregation of data from multiple factories and companies—with their permission—and performing machine analytics that provide each manufacturer with information that enables them to improve performance. As such, EU regulations prescribing a particular business model or specific contract language are likely to limit, not advance, innovation.

Trade

Trade policy will play a key role in shaping ICT development and adoption, both in Europe and across the world. This section examines global trade policy trends, digital trade policies, and how to develop an integrated European services market.

Trade Policy Trends

Underlying and helping to shape CAS development and competitiveness is the nature and evolution of the global trading system. The last two waves of IT development have led to and supported the emergence of broad global value chains and the disaggregation of production into component parts. Coupled with the policies of low-wage developing nations—particularly China, but also India and other nations—a new global division of labor has emerged, with a higher share of lower-value-added work being done in these nations.

If this new global division of labor were the only major dynamic happening, trade policy would be much simpler. Instead, the global economy has seen an unprecedented rise in "innovation mercantilism": a set of policies put in place to unfairly win in the competition for advanced industries. This includes forced technology transfer, cyberespionage, development of domestic-only technology standards, local production requirements for market access, and massive subsidies of technology firms. China is the leading proponent of this type of development strategy, but a number of other nations, including Brazil, India, Indonesia, Russia, and Vietnam have embraced at least a sizeable suite of these kinds of policies.[206]

Unfortunately, the World Trade Organization (WTO) is not in a position to fully respond to these challenges, in part because many of these unfair trade practices are not covered by WTO agreements (e.g., cyberespionage, subsidies) or are unenforceable because certain nations do not put their unfair policies in written form by which action can be taken against. This is one reason why the current focus by the EU on advancing a WTO reform agenda is so important.

These developments have several important implications for the EU digital economy. The first relates to trade relations with the United States. While it is unclear how U.S. trade policy will evolve under the Trump administration, it does appear the Trump administration's imposition of tariffs on China are not designed principally for protectionist purposes but rather to roll back unfair Chinese trading practices. Whether warranted or not, this also appears to motivate the administration's efforts regarding EU trade, including in automobiles, where the administration believes the playing field is unlevel in part because of differing tariff levels and the use of border-adjustable value-added taxes by European countries.

Moreover, President Trump has ushered in a new era in U.S. trade policy, and it will be difficult for any subsequent administration—Democratic or Republican—to go back to the old operating framework. This framework was premised on the belief that most nations are evolving to become free traders, and that one-sided trade (free trade on the U.S. side and mercantilism on the other) was still in the United States' national interest. This view has now been seriously called into question, including by many in the trade policy establishment. As such, future U.S. administrations will likely take a tougher stance to push back against foreign mercantilist practices than previous administrations.

At this time, it is not clear whether the Trump administration's efforts with China will succeed. Regardless, unfair trade practices from China pose a threat to the ability of Europe to prosper in the CAS economy. China's goal, in part articulated in its *Made in China 2025* plan, is to wrest leadership in a wide array of advanced industries (including Industry

4.0, AI, 5G, robotics, and electric and autonomous vehicles) not just from the United States but also Europe. As such, the United States and the EU need to work more closely together to fight against the distortions of global trade China is engaging in. This should involve joint pressure on the WTO to have it evolve in ways that allow it to play a stronger role policing mercantilist nations such as China.[207] Combined multilateral pressure from the United States and Europe will also be key to limiting the worst of the Chinese government's policies. Failure to do so will not only cede leadership in the industries critical to the next wave, it will also slow the overall pace of global innovation in these areas.

Whether both nations can agree to this—and whether even joint efforts will be successful—is uncertain. What does seem likely, at least over the moderate term, is that there will be some breakdown of globally integrated markets and supply chains. There are simply too many nations today that are demanding local production in exchange for market access, and in response, many multinationals have begun to resign themselves to a world wherein they introduce local production facilities to serve local markets.

Unfair Chinese trade practices pose a threat to the ability of Europe to prosper in the CAS economy.

Another challenge facing Europe is the threat from Chinese government-backed acquisitions of European CAS firms.[208] A core component of China's *Made in China 2025* plan is to acquire foreign advanced-technology capabilities through state-backed and subsidized acquisitions of foreign companies.[209] Europe experienced this firsthand with the Chinese acquisition of Germany's Kuka, one of the world's leading developers of robotics and automation technologies. The U.S. Congress recently passed the Foreign Investment Risk Review Modernization Act (FIRRMA) that modernized the Committee on Foreign Investment in the U.S. process to significantly strengthen the ability and authority of the U.S. government to limit the ability of firms in state-capitalist economies to acquire, in whole or in part, U.S. advanced technology companies, and potentially to limit forced technology transfer.[210] **The European Commission needs the authority to review and approve or reject investments in the EU—including acquisitions and equity investments—from firms in state capitalist economies.** Relying on national governments alone will result in a patchwork of protections, with lower-income EU nations being more willing to sell assets at a premium price to foreign government-backed firms.

Digital Trade Policies

Trade in the 21st century is increasingly digital. But to ensure a robust level of digitally enabled trade, Europe needs to address two key issues: 1) removing barriers to data flows and 2) improving market access for trade in digital services, both within Europe and with the rest of the world.

The EU has not yet fully followed through on its assertion that the free flow of data is a prerequisite for a competitive data economy within the Digital Single Market.[211] Data will naturally flow across borders unless governments enact artificial barriers that prevent it from doing so. But the EU's approach has made this more difficult by introducing artificial differences between personal and nonpersonal data, and between data flows within and outside the region. This has occurred in part because of the EU's focus on the geography of data storage, rather than on the legal framework for holding firms accountable for managing EU citizens' personal data (wherever it is stored) and on how firms ensure they can provide regulatory authorities with timely access to this data when presented with a legitimate request.

In June 2018, the Commission came to a provisional agreement on regulating the free flow of nonpersonal data in the EU. The agreement highlighted a Deloitte study that estimated removing internal barriers to data flows would generate additional economic growth of 4 percent of European GDP by 2020.[212] Furthermore, the agreement pointed out that some of the main obstacles to data flows are due to data localization by public authorities and the legal uncertainty firms experience regarding the complex legal patchwork around cross-border data storage and processing in many different sectors, situations, and countries across Europe.

The same principle of "duty of care" for data should also apply for data that flows outside of the EU.

The EU has recognized the impact of digitalization on trade, as outlined in the EU's *Trade for all: Towards a more responsible trade and investment policy* report, which highlights the growing importance of digital trade and data, and establishes the overarching goal to "set rules for e-commerce and cross-border data flows and tackle new forms of digital protectionism, in full compliance with and without prejudice to the EU's data protection and data privacy rules."[213]

Europe needs to continue to work to ensure the existence of a free flow of data, including personal data, within the EU. One way to achieve this is to introduce duty-of-care provisions whereby domestic regulators hold companies responsible for any breaches of data-privacy laws—regardless of where the company stores data. For example, if a French firm has data on French persons and stores it in Slovenia, French laws apply to that data. Of course, after the passage of the GDPR, this issue should be moot.[214]

Yet the same principle of "duty of care" for data should also apply for data that flows outside of the EU. **The EU should make it clear in law that companies that do business in the EU (and thereby have a legal nexus there) are 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 of an affiliate or business partner in another nation.** In other words, EU protections should travel with the data, regardless of where that data travels.

Embracing this duty of care standard has implications for EU trade policy. The Commission does not directly deal with issues relating to data flows in its trade agreements, as it does not want to expose them to hypothetical legal challenges.[215] Instead, the Commission prefers to address issues related to data flows, especially of EU personal data, outside the text of trade agreements as part of "adequacy" determinations, most recently with Canada and Japan.[216] The Commission focuses on certifying that countries provide an adequate level of protection equivalent to what Europe provides at home. Outside of an adequacy determination, the only other tools to manage transfer of EU personal data are the EU-U.S. Privacy Shield Framework and certain legal tools (such as binding corporate rules and standard contractual clauses). However, the possibility that both the Privacy Shield and these legal tools may be invalidated does exist, as they are currently the subject of legal challenges in Europe.[217]

While Europe's adequacy approach can, by definition, work for other nations with similar privacy regulatory regimes, it is more problematic in dealing with the majority of nations that have less-stringent regimes, such as China. Moreover, the EU's own process and criteria for assessing adequacy is not clear, nor is it comprehensive, covering a disparate collection of 11 countries—from Israel to the Faroe Islands, Guernsey to the Isle of Man.

As such, **the EU should develop provisions within the text of its trade agreements—not outside them—to protect the role data flows play in digital trade in order to ensure other nations do not use privacy as a cover for digital protectionism, as it would make these measures subject to a trade dispute.** It can do this if it embraces a duty of care standard to protect the privacy of EU residents, not by where it allows data to flow, but by holding companies accountable for abiding by the GDPR and other related laws and regulations regardless of where they store and process data.

To its credit, the EU is considering language to include data flows in trade agreements.[218] The opening sections in the European Commission's draft set of digital trade provisions prohibits digital trade barriers, such as data localization policies, that block cross-border data flows. This is important, because the rise of such data-localization policies globally makes strong and enforceable rules essential to the EU promoting an open global digital economy and allowing EU firms to engage in robust digital trade.[219]

Unfortunately, the European Commission's draft proposal continues to reflect its divided membership. The preceding provision prohibiting barriers to data flows has been rendered problematic by a follow-on section about privacy, stating that any participating nation can enact whatever measures it "deems appropriate to ensure the protection of personal data and privacy, including through the adoption and application of rules for the cross-border transfer of personal data." Essentially, this means that as long as a country states that data localization is for data privacy, it is valid within the EU trade policy framework, thus legitimizing the very policies of other nations the EU vision rightly opposes.

Instead of a broad, self-judging exception for privacy, the EU should develop trade agreement provisions that cover the sizable range of legitimate privacy policies countries use. **Most importantly, Europe's digital trade agreement provisions should emphasize that firms will be held accountable for ensuring a country's data protection rules flow with the data, regardless of the privacy policies that exist in the nations where the data is stored.**

Developing an Integrated European Services Market

For the EU to improve productivity and fully benefit from digital technologies, it needs to take further action to develop a truly integrated services market. This is particularly important because service industries are ripe for CAS transformation, although this will need to be supported by larger, more-integrated markets to give firms of all sizes greater economies of scale.

Given that most European economies increasingly rely on services for their value added—in Germany, for example, service industries account for 70 percent of value added, and in many other European economies the share is even higher—ensuring services transformation through CAS technologies is key to competitiveness and productivity.[220] While developing a more-integrated services market involves getting individual member states to make many of the necessary changes (given that this involves national, not EU, responsibilities) and address issues pertaining to domestic regulatory practices, this is a challenge the Commission can help address.

Services market integration is critical for digital services, as regulations often limit access for digital challengers, including start-ups.[221] These barriers prevent the exploitation of economies of scale and thereby threaten the business models of new, ICT-based services firms. Service trade barriers also reduce imports in restricted sectors, affect local firms' competitiveness in international markets, and reduce foreign firms' access to local markets. There are also negative knock-on consequences for downstream users of these services and the potential for European firms to play a greater role in emerging global value chains.[222]

Accordingly, there is a widespread consensus that Europe needs to do more here. For example, the consulting firm Copenhagen Economics wrote, "From a business perspective, the reality of the Single Market for services falls short of expectations."[223]

The overarching goal for the EU and its member states should be to remove harmful and unnecessary rules, improve existing rules, and help create good rules for new issues. To do this, **the Commission needs to develop 1) a clear process to identify barriers to entry and operation in service markets, 2) a tool to assess these barriers to determine whether they are proportionate and in line with best practices, and 3) reporting and transparency mechanisms to publicize relevant rules and regulations, alongside a parallel effort to ensure regulatory agencies have the capability to develop, enact, and enforce relevant rules and laws.**[224] The European Commission's recent work on services as part of the Single Market strategy touches on parts of these and provides a solid foundation to build upon, yet also highlights where further ambition, leadership, and policy action are needed to achieve a broad base of consistent action among EU member states.[225]

Regulatory restrictions pertaining to services trade should be limited to measures needed for legitimate public-interest purposes—such as for health, education, consumer protection, and environmental or national security concerns. Regulations undertaken in pursuit of such public policy goals target perceived market failures (such as competition policy or such negative externalities as environmental impacts) or a particular social equity objective (such as universal service access). The challenge is to design a regulatory framework for services, especially those involving digital technologies, that is clear, reasonable, proportionate, and non/least-trade distorting. There are clearly principles regulators can rely on to limit the negative impact of regulation on innovation and, in some cases, to spur innovation.[226]

The goal of enabling economies of scale and network efforts, as well as improvements in productivity and innovation, for digital services extends beyond the EU to the global market. The economies of scale provided by ICTs mean that expanded services trade will enable higher productivity and lower costs for consumers, and spur further investments in innovation. However, liberalization of trade in services at the global level has long taken a backseat to trade in goods, despite services accounting for approximately 70 percent of the global economy.

Data can transform how the public and private sectors work and deliver services—enabling them to adopt more efficient and effective practices.

New rules are needed as digital technologies are causing many more services can now, with the right rules, be traded across borders. And some services tasks are increasingly splintered into discrete components, some of which can be performed and sourced remotely. This is considered the "second unbundling" of international trade, following the geographic separation of consumption and production of physical goods that occurred following the reduction in transportation costs in the 1800s.[227] These two interrelated trends—increased digitalization and increased unbundling of services—have created a global market for services tasks that has contributed to the tripling of services trade over the past 15 years.[228]

However, tradable services—such as retail, professional and business services, finance and insurance, and entertainment services—too often face markets that are not (or are only partially) open to foreign competition and subject to "behind-the-border" regulations that limit trade.[229] Too many policymakers are willing to accept a future with too many small, inefficient local service firms and the accompanying low productivity and income growth they produce, rather than opening up domestic markets to global services trade.[230] Again, barriers to services trade are most clearly visible when leading firms—often large and on the cutting edge of technology and business practices—enter service sectors that have traditionally been heavily protected from competition, a protection that results in large numbers of small and inefficient firms. Current services market access rights were largely set in the mid-1990s by the General Agreement on Trade in Services (GATS), when the Internet as we know it barely existed and services trade was nowhere near as important.

To address this, **the EU should take a leading role in reviving negotiations over an ambitious Trade in Services Agreement (TISA),** which stalled at the end of 2016. A prerequisite to do this would be the EU modifying its approach to intraregional and international data flows, as its position on the issue of data was a major cause both for continuous delays in TISA negotiations and in its ultimate stalling. TISA represents the most-relevant vehicle to achieve a more open global market for digital services. The 23 economies involved in TISA comprise the majority of the world's services activity, and also share a broad, high-standard ambition to upgrade international trade rules for the modern era. Among other provisions, an ambitious TISA agenda should include rules that protect the free flow of data for all services and categories of data, improve services market access, introduce a permanent commitment not to levy duties on digital products, and improve transparency and reporting rules for regulations that impact market entry and operations for digital services.[231]

Resources for Firms

Firms' productivity, innovation, and competitiveness depend in part on the prevalence and quality of external resources, including infrastructure, skills, data, and scientific and engineering research.

Data

Data can transform how the public and private sectors work and deliver services—enabling them to adopt more efficient and effective practices. For example, as a result of greater data access and use, the value of the data economy in Europe could increase in value from €300 billion (1.99 percent of GDP) in 2016 to €739 billion (4 percent of GDP) by 2020. In addition, open data initiatives are predicted to have the ability to save Europe's governments €1.7 billion by 2020.[232]

Data is also enabling important innovations in many sectors. For example, in education, data can help government leaders create more effective education policy, schools operate more efficiently, families find the best schools, teachers discover the most effective lessons, and students learn better. Data is also critical to the health and well-being of individuals, and is being used to improve virtually every aspect of health care, from developing new drugs to delivering care to patients. Increased use of data in health care offers a broad range of benefits, including more personalized and coordinated care, better quality, faster treatment development, and lower costs. Finally, as noted by European Commission Vice President Andrus Ansip, "Without data, we will not make the most of artificial intelligence, high-performance computing, and other technological advances."[233]

The EU and member nations have taken important steps in this direction. The Payment Services Directive (PSD2) was a helpful policy that has made banking data more accessible and increased competition. And the United Kingdom's Open Banking Standard demonstrates how this approach could be taken further by requiring banks to make their data available in a standardized format and therefore it easier for third parties to access and use to develop further innovations for consumers. In the case of both PSD2 and the United Kingdom's Open Banking Standard, the overriding goal is to ensure consumers can share their personal financial data with third parties and increase market transparency about bank fees—not to force companies to turn over their own proprietary data.

EU policymakers are rightly focused on promoting the adoption and use of artificial intelligence, and many recognize that the widespread availability of data is necessary for many AI applications, particularly those that use machine learning. Policymakers should facilitate the voluntary sharing of data to promote innovation and other societal benefits. Often, the public and private sectors hold valuable sensitive data but lack mechanisms to securely and efficiently share it with one another and academia. The United Kingdom is developing a program of "data trusts" to facilitate the voluntary sharing of data that would not otherwise be made publicly available due to its proprietary or sensitive nature, but has high value for AI applications.

Europe can also do more to promote open government data. While member states must follow the directive on the reuse of public-sector information, which gives citizens the right to access certain public data, this directive leaves it up to member states to determine what information can be made available and in what format. In addition, most EU countries have signed on to the Open Government Declaration, a global open data initiative led by the Open Government Partnership (OGP), an international organization promoting more open, effective, and accountable government. However, OGP's open data initiative focuses narrowly on transparency in government, and overlooks the significant commercial and efficiency payoffs a broader and deeper commitment to open data could deliver for Europe.

Discussions about data need to balance legitimate needs for privacy with those for data innovation by EU firms.

A good model for open government data is the G8 Open Data Charter, which, as well as supporting the release of data to promote transparency, is more explicit about the quality and format in which data should be released and, importantly, adds innovation as a reason to release data.[234] As the four EU members of the G8 (now G7)—France, Germany, Italy, and the United Kingdom—have all signed up to the charter, and even the EU has endorsed the G8 Open Data Charter for its own institutions, all other European countries should make the same pledge. Broadening Europe's open data commitments to include data innovation will be particularly important for countries that are seeking to thrive in the data economy and take advantage of the economic potential of open data.

Policymakers should remember that without data collection, data access has no value. For many years, policymakers have sought to address the "digital divide"—the social and economic disadvantages that may result from a lack of access to technology.[235] Now EU policymakers should begin a concerted effort to address the "data divide"—the social and economic inequalities that may result from a lack of collection or use of data about an individual or community. Already, gaps are appearing where certain groups of individuals do not have data collected about them or their communities because of where they live. If this trend toward a data divide continues, we might even see the rise of "data deserts"—areas characterized by a lack of access to high-quality data that may be used to generate social and economic benefits. To address this, EU governments should ensure official statistics and surveys include all population groups, with a particular focus on including historically uncounted populations. In addition, governments should digitize their civil registration offices to ensure data from key legal documents, such as birth, death, and marriage certificates, can be integrated into national vital statistics.

Data innovation does not receive enough attention. Discussions about data need to balance legitimate needs for privacy with those for data innovation by EU firms. To strike this balance, **every EU member state should appoint a chief digital officer to not only champion data innovation domestically, but also serve on a new, independent, EU-wide advisory panel charged with counseling the EU on how to seize opportunities to innovate with data and AI and related tools, and develop a cohesive vision and strategy for capturing the full benefits of data-driven innovation in Europe.**

France was the first country in the EU to appoint a chief digital officer—Henri Verdier, director of Etalab, which oversees France's open data portal—to the position in September of 2014.[236] His role is primarily concerned with how the French government generates, governs, and uses data.[237] While data-driven innovation in the public sector is important, EU member states should direct their chief digital officers to also encourage data-driven innovation in society more broadly, including in the private sector.

Finally, there is the issue of data ownership. There is increasing dialogue and debate about the issue, including who can own what data, at what times. In general, instituting data ownership rights (as opposed to rights to creative content) in law or regulation runs the risk of limiting innovation, including of business models.

Data can either be related to a person or a "machine," although the dividing lines are not always strict. An example of machine data would be data from a farmer's sensors in his field reporting data on soil moisture, temperature, and growth rates from a machine. Personal data is data such as an individual's date of birth, emails, and health records.

It is worth making a distinction between the four main kinds of personally identifiable information (PII), which is information that can be used to distinguish or identify an individual, is linked, or is reasonably linkable to an individual.[238]

The first category is observable information, which is personal information that can be perceived firsthand by other individuals. This category includes both observable personal information created by the individual about themselves, as well as observable personal information captured by a third party. An example of the former is personal correspondence, such as letters or emails a person has written. Examples of the latter primarily come from recorded media, such as video surveillance (e.g., CCTV camera footage), photographs (e.g., personal photos), or audio recordings (e.g., recording of a conversation).

The second category of information is observed information, which is information collected about an individual based on a third party's observation, or provided by the individual but does not allow someone else to replicate the observation. This data can encompass a wide variety of information that describes an individual, such as their basic information (e.g., place of birth, date of birth, etc.), physical traits (e.g., weight, eye color, etc.), personal preferences (e.g., likes and dislikes, political views, search history, reading habits, media consumption, etc.), and social traits (e.g., degrees, religious affiliations, nationality, criminal history, etc.).

The third type is computed information, which is information inferred or derived from observable or observed information.[239] Computed information is produced when observable or observed information is manipulated through computation to produce new information that describes an individual in some way. For example, companies construct online advertising profiles for consumers based on many different sources of observed information, such as direct-mail responses, search history, and demographic information. Biometrics are derived through a computational process involving scans of unique physical characteristics on a person's body.

Finally, associated information is information a third party associates with an individual. Associated information, by itself and unlike the other three categories, does not provide any descriptive information about an individual. For example, a library card number alone does not provide any information about its owner. There are many different types of associated information, such as government identification information, contact information, and device identifiers (e.g., IP addresses, MAC address, browser cookies, etc.). Table 5 summarizes these types of information.

Table 5: Types of Information, With Examples for Each

Type of Information	Examples
Observable Information	Videos, emails, recordings, etc.
Observed Information	Geolocation, date of birth, search history, etc.
Computed Information	Advertising profiles, biometrics, credit scores, etc.
Associated Information	Social Security numbers, IP addresses, land titles, etc.

With observable information, there often can be a clear owner, particularly when it involves an original work of authorship. Clearly, data that collectively forms a video, sound recording, image, or text can be copyrighted. With observed information, the issue of rights relates to the question of who contributed the "labor" to the data (and why). For data that is just "out there," such as someone's date of birth, there should be no rights to control it.[240] But a lot of observed data is not widely available and is provided to other parties, such as social networks (e.g., posts/status updates). This involves user input, so clearly the user should have some rights. But when one goes online, organizations (e.g., Facebook, Wikipedia, Amazon, etc.) possess one's information. Here, companies should have the right to use the data, but be governed by their privacy policies, the ability of users to opt out of secondary use, and any privacy rules governing the rights of consumers to data deletion.

While it is also observed data, network traffic or SSID broadcasts are fairly incidental "data exhaust," so if a company is collecting that information, they should have the rights to it.

Overall, to say that the companies a citizen shares information with have no legal rights to that at least some of that data cannot be correct. This is especially true if the company using personal data curates it (fixes errors such as an incorrect birthday, for example) or combines it in a way to make the overall database more valuable. But these companies should no more be able to own the rights to data they have about a person than a person should be able to own data about another person. This is because, as U.K. attorney Jo Joyce wrote, "No one can truly own a piece of data, the only thing that can be possessed is an aggregation or collection of such data, provided there has been a relevant investment in carrying out that aggregation or collection."[241] To be clear, an aggregation of bits into the form of a photo is something that does and should have intellectual property rights.

With computed information, the rights should accrue to the party that performed the lion's share of the work—e.g., computing. For example, when a company spends time and effort to create an advertising profile for an individual, that company should have the rights to that data, presuming they complied with all relevant privacy laws and regulations. Finally, with associated information, the organizations that produced the information should have primary rights. But when it represents an individual, that individual clearly has usage rights.

But notwithstanding these differences, there have been broad calls for individuals to have ownership rights to their data. Every day, hundreds of millions of people go online to search the web, watch videos, read content, and catch up with friends—all without paying a single cent. But some critics deride this free ecosystem, claiming that not only are unsuspecting consumers "paying" for these services with their data, but they are also getting a rotten deal. Many argue that individuals should have exclusive legal rights to all "their" personal data so that others can never use it without their permission. For example, a recent article in the *Financial Times* entitled "Digital privacy rights require data ownership" is emblematic of the dominant framing: Ownership implies sovereignty over property, but unlike property, data can be copied, which means sharing it is not a zero-sum game, such as with property transfers.[242]

The exchange of data is a fundamentally different exchange of value than other transactions. Data is nonrivalrous; many different companies can collect, share, and use the same data simultaneously. Similarly, when consumers pay with data to access a website, they still have the same amount of data after the transaction as before. As a result, users have an infinite resource available to them to access free online services. In other words, if a person gives another person 10 euros, they have 10 fewer euros. But if they tell another person that they are a football fan, then both simply know that information. Sharing personal data does not preclude a person from sharing the same data to access any number of services.

When consumers allow companies to use their data, they allow value to be created. Ad-supported digital services turn data into value by functioning as two-sided markets that connect consumers and advertisers. Users get access to a free service and advertisers get access to an audience for its ads. In most cases, the advertiser does not even know which users see their ad, only that the ad is placed in front of a targeted group of people, such as people who live in Brussels or have an interest in travel. Ad-supported digital services represent a key digital-era business model.

ICT R&D

Support of ICT R&D is an important policy tool to spur more ICT innovation and firm competitiveness. Although the EU lags behind the United States in ICT R&D as a share of GDP, bold increases in funding could help Europe close this gap. To that end, proposals for Europe 2020, as well as R&D proposals from DG Connect, promise to increase support for ICT R&D.

However, to be more effective, the EU should consider significant reforms in two main areas. The first relates to whether projects are bottom-up or top-down. Currently, the Commission sees the process for allocating funds for Open Science as predominantly bottom-up, whereby principal investigators propose projects based on their own interests. In contrast, the Horizon 2020 process for allocating support for industrial R&D is very much top-down, with the Commission identifying specific areas to be funded. The Commission should consider reversing this orientation. In particular, **the Commission should adopt an ICT R&D funding system that lets industry decide what areas it is most interested in participating in. At the same time, it should identify areas of importance for ICT research and devote funds to individual academic researchers and academic research centers for projects in these areas.**

The second issue relates to who gets funded and in what form. Currently, a large share of EU funding goes to individual projects. In the Horizon 2020 program, over 1,900 industrial projects were funded as of late 2018.[243] The challenge is the process of applying for grants can be relatively burdensome. At least in the area of ICT R&D, **the Commission should reduce its role as a "retail" funder and instead fund a modest number of industry-university R&D centers**. One key model is the U.S. Industry-University Cooperative Research Center (I/UCRC) program.[244] The I/UCRC program forges partnerships between universities and industry, featuring industrially relevant fundamental research, industrial support of and collaboration in research and education, and direct transfer of university-developed ideas, research results, and technology to incumbent and start-up firms.

While funding is modest, the program has achieved outsized results, not only in terms of commercializing research, but in saving participating companies money on research expenditures.[245] The I/UCRCs have also had important impacts on expanding STEM graduate education, including increasing the number of female graduates. One study of

I/UCRCs found that these "centers may constitute an institutional context in which some aspects of gender equity in science may be achieved."[246]

An argument some defenders of the current academic system make against industry-university partnerships such as the I/UCRC model is such partnerships limit academic freedom, particularly of the graduate students doing research. However, this does not appear to be the case. One study that used a stratified sample of graduate students from the same two engineering departments at six U.S. universities found that "the results failed to support claims that sponsorship by industry negatively affects student experiences or outcomes," and that there was no statistically significant difference in levels of academic freedom between industry-sponsored research projects and others.[247]

One key factor contributing to the success of the I/UCRC program is industry must provide matching funds. For every NSF dollar, industry must contribute at least 4.3 dollars. While this match ratio is probably too high, requiring some industry match helps ensure not only that the research is industrially relevant, but also that industry cares about ensuring their investment translates into real bottom-line results. In the I/UCRCs, graduate research projects are often chosen by a vote among the center's industry members, and each project so selected typically has an industry mentor alongside the faculty advisor. Not only is the research itself more product- and team-oriented, but these same industry members become close enough to the university faculty that they are then available to define and lead undergraduate design projects as well. Thus, "real design, by real teams, for real customers" becomes accessible to both graduate and undergraduate students—as evidenced by a study that shows the I/UCRCs are producing a minimum of 1.04 spin-offs per year, or 0.17 spin-off/start-ups per year per million dollars.[248]

As such, **the Commission should establish an ICT-based I/UCRC program, wherein the research areas are determined by universities in partnership with industry, and no funding is available unless industry provides at least half the funding in cash.** In order to ensure regional cohesion, the Commission could require that industry supporters come from at least three EU nations.

The Commission should also focus on another challenge. In the United States, large technology companies are increasingly hiring top professors doing research in AI, robotics, and other advanced ICT-related fields. Leading academics spend much of their time grant writing and often face limits on their salaries, making them more likely to move to industry. The problem, of course, is that while individual firms may benefit, it weakens the overall innovation ecosystem as there are fewer top-quality university researchers to train the next generation. As such, **the Commission should establish a program that awards €1 million each year for five years to the top 100 or so academic researchers doing work in advanced ICT areas industry values.**

Finally, the Parliament and the Commission overall should support **the Directorate General for Research and Innovation's efforts to increase funding for research and**

development in robotics and artificial intelligence. One step to consider would be to establish a new directorate focused on supporting research in these two fields.

Labor Markets and Digital Skills

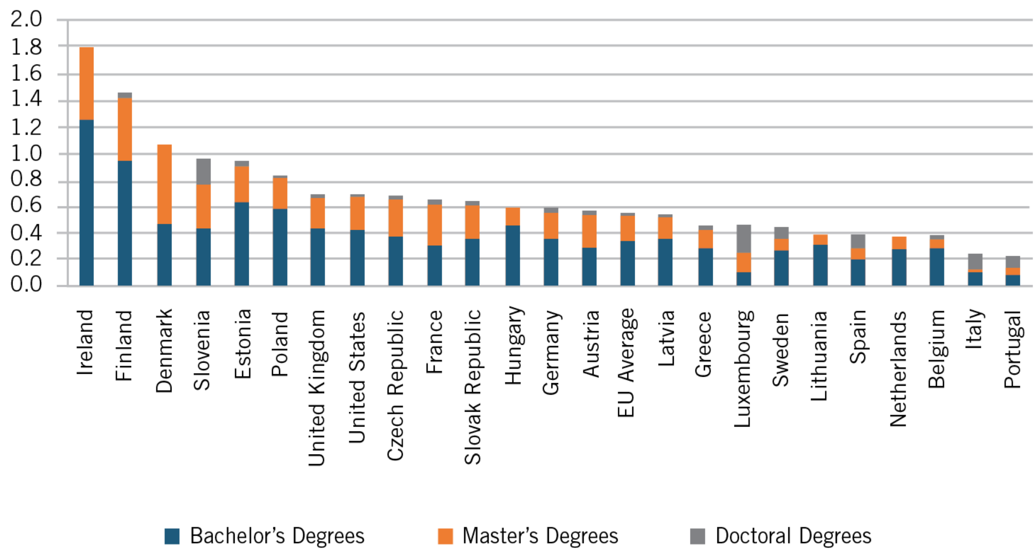
There is widespread concern that an increasing share of workers will be contingent workers—many doing work through technology platforms—which will necessitate a serious reform of labor market regulations. For example, the U.S. gig worker matching platform Upwork recently predicted, without evidence, that within a decade the majority of U.S. workers will be freelancers.[249] Some point to a study by the U.S. Federal Reserve that discovered 31 percent of U.S. adults engage in gig work.[250] But a closer examination of this study suggests that most of these people are making very little money. Three-quarters of these workers earn less than 10 percent of household income from this work and typically spend just five hours a month at it. For example, a person would be classified as a gig worker if they were employed full time in an insurance firm but had a hobby making earrings and selling them on Etsy or babysitting a few nights a week for neighbors.

A much more important labor market issue for Europe than the purported rise of the gig economy is the state of ICT skills.

To be sure, gig economy work has grown in the last decade, but much of it appears to have been a fallout of the Great Recession, when full-time, permanent work was scarce. Moreover, even with the growth of Uber, Task Rabbit, and other work-sharing platforms, in 2015, only about 600,000 U.S. workers were employed this way. Moreover, the share of the U.S. workforce that was self-employed in 2016 was at an all-time low of less than 7 percent.[251] In a widely cited 2016 study, Lawrence Katz and Alan Krueger found an increase in alternative-work arrangements from 2005 to 2015 that included workers in temp agencies, independent contractors, and contract workers. (These are all categories wherein technology has not driven their growth.) Gig economy jobs through online platforms accounted for only around 0.5 percent of U.S. jobs in 2015.[252] However, the authors recently issued a retraction, admitting their original study was erroneous and gig economy jobs had grown only one to two percentage points, rather than the five points they had initially found.[253] Moreover, in the definitive survey of contingent workers, the U.S. Bureau of Labor Statistics recently found that just 3.7 percent of U.S. workers are contingent workers, a number that has actually declined since 2005.[254] And there's no reason to believe self-employment will grow significantly in the future as long as the economy does not fall into recession.

A much more important labor market issue for Europe than the purported rise of the gig economy is the state of ICT skills. In the United States 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, as figure 21 shows. In addition, OECD data shows that on the one hand the share of adults lacking basic computer skills is higher in some EU nations compared with the United States, but lower in other EU nations, including Belgium, Finland, Greece, Poland, Italy, Spain, and France.[255] However, according to OECD, increasing the provision of ICT training to low-skilled EU employees from a low level (Greece) to the sample maximum (Denmark) could increase the adoption rates of cloud computing and digital front-office technologies (such as customer-relationship management) by around 7 percentage points in knowledge-intensive industries.[256]

Figure 21: Computing Degrees per 1,000 People[257]



It also appears the United States leads Europe in development of AI skills. A study by LinkedIn examined 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).[258]

Bolstering K–12 computer science (CS) education is a key step member states and the Commission can take to bolster the ICT capacity of future workforces. In fact, many nations around the world have also begun to reform their CS curricula with an eye toward success in the global marketplace.[259] For instance, Finland, Denmark, Australia, Singapore, and the United Kingdom have all taken steps to reform CS education.[260] These actions include introducing CS to primary school students, adding more deep concepts to curricula, and training more specialized teachers.

Some nations have begun to integrate digital skills and algorithmic thinking into the general curriculum. For example, Finland has worked to integrate algorithmic thinking into its national core curriculum as a skill separate from CS for all children older than five years of age. In 2013, the United Kingdom mandated that students ages 5 to 14 take computer science, and for all high school students to have the option to take the course.[261] Through this measure, the United Kingdom hopes to be able to address its own impending technology-skills shortage, and help fill the estimated 249,000 tech-skilled jobs that will be available in the United Kingdom by 2020.[262] However, though CS is now required, the

United Kingdom is still struggling to train the computer science teachers needed to teach every primary student in the country.

There are a number of steps countries—or states, provinces, or regions therein—can take. The EU should make it a goal that every K–12 high school offer computer science education to those who want it (even if it means making courses available online through massively open online courses, or MOOCs). For example, Finland has a free MOOC on computer science operated by the University of Helsinki and Reaktor. In addition, schools need to do more to ensure more high school students take statistics and learn data skills.

One reason computer science sometimes is not offered is a lack of qualified teachers. Where this is a challenge in Europe, **the Commission could provide matching grants to relevant states, cities, provinces, or regions for establishing teacher-certification programs in computer science.** To provide more students with the opportunity to learn computer science in a rigorous manner from a certified teacher, all EU member states should have certification programs that allow graduate students in education fields to become teachers that specialize in computer science. The EU could also **subsidize the cost of certifications and master's programs for prospective teachers who successfully teach computer science for five years.** Subsidizing the cost of certification and providing higher wages for teachers who earn certificates can incentivize teachers to acquire them and make teaching a more attractive option for people who are also in high demand in the private sector.

Europe can also further build on public-private partnerships for computer science education and digital skills development. For instance, in the United States, Microsoft's Imagine Academy partnered with the North Carolina Department of Public Instruction to make available Imagine Academy subscriptions, which teach key digital workplace skills, to all 628 public high schools in the state to ensure students are able to earn certification as either a Microsoft Office Specialist (MOS) or Microsoft Technical Associate (MTA).[263] The designations give high school students a strong upper hand in their first foray into the labor market by signaling to prospective employers their training in some of Microsoft's most ubiquitous office productivity software, such as its Office suite. Likewise, in the United Kingdom, Microsoft offers three Early in Career pathways: Graduate, Intern, and Apprentice.[264] The pathways, intended for students ages 18 to 24, include a range of different job roles that help teach digital skills. Microsoft's IT Apprentice program gives participants both a nationally recognized apprenticeship qualification and support to help them continue their careers at Microsoft.[265]

The Commission should also fund a pilot program that would establish more maker spaces in European high schools. These are spaces where students can use digital tools such as computer-aided design and 3D printing to gain hands-on experience in production and design. This program could be modeled on DARPA's Manufacturing Experimentation and Outreach (MENTOR) program, which introduces new design tools and collaborative practices to U.S. high school students.[266]

Broadband Infrastructure

A digital economy relies on robust digital broadband infrastructure, both fixed and mobile. But Europe lags behind the United States and some other nations in broadband speeds and investment.[267]

The strategic objectives for 2025 outlined in the Commission's 2016 Digital Agenda—connecting anchor institutions with gigabit networks, widespread 100 Mbps connectivity, and urban 5G deployment—are laudable.[268] But it will be difficult to achieve them without either large subsidies or an improvement of market conditions to drive the investment needed—or both. While some EU nations have world-leading broadband and wireless infrastructures—particularly Nordic nations—many EU nations do not. According to Cisco, 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.[269] In 2018, around half of mobile connections were 4G in Europe, compared with over 75 percent in the United States.[270] And the market intelligence firm GSMA Intelligence predicts that by 2025, 49 percent of U.S. mobile connections will be on 5G networks, compared with just 29 percent in Europe.[271]

Competition in high-fixed cost industries such as telecommunications is not an unalloyed good—a smaller number of providers can more efficiently provide robust service at a lower cost.

One challenge for the EU is its broadband providers are smaller. But their small size does not mean more competition and lower profits. In fact, profit rates for EU and U.S. broadband providers appear to be nearly the same.[272] The mobile wireless sector provides a good example of the challenges—each EU member state generally has at least three or four providers, with only the largest players operating in multiple markets. The largest EU mobile operators, Vodafone and Telefónica, offer services that are available to about two-thirds of the European population, but the scale of operators drops off quickly after that, with many wireless firms operating in only a single member state.[273] Added scale would reduce the costs of provider service per subscriber, greatly reduce the need for roaming charges, encourage investment and more rapid transition to 5G networks, and provide others with larger platforms to innovate on top of the network—a true boon to European businesses and consumers. As GSMA Intelligence wrote, "However, without size or scale, the long-term viability for mobile-only businesses is increasingly challenging."[274] Likewise, as Hossein Moiin, former CTO of Nokia Networks, has explained, "In the U.S. you have a country of 300 million people and only four operators, but in the EU you have many operators. Such fragmentation does not help the business case for investors. There are no technological barriers; it's just a question of economics and return on investment."[275]

The European Commission has recognized that spectrum management is a critical issue and that the Commission has a key role to play in advancing spectrum management. The Commission has articulated three main goals for its reforms to spectrum management: 1) harmonization of spectrum access conditions, with the goal of enabling economies of scale; 2) encouraging more efficient use of spectrum; and 3) making available better information about the current and future use of spectrum.[276] The Commission should continue with this work.

Another factor limiting investment is price regulations and wholesale unbundling requirements.[277] As such, **wherever there are at least two competing providers in a market, the Commission should generally aim to deregulate price regulations and wholesale requirements.** This is apparently contrary to current policy, judging by recent comments from the Commission on wholesale regulations in the Netherlands.[278] In that filing, the Commission supported the finding that both KPN and Vodafone are jointly dominant in the market. The Netherlands enjoys relatively extensive cable deployment compared with the rest of the EU, with cable networks deployed to nearly 95 percent of households.[279] The Netherlands enjoys relatively vigorous facilities-based competition in the fixed broadband market. There are well-known trade-offs between more extensive access regulations, with mandatory unbundling or wholesale obligations generating both more choices for consumers and an effective control on prices, but undermining the incentive for firms to invest in deployment, innovate to provide new technologies, or create innovative business models that can contest the market.[280]

Access regulations were historically aimed, at least in part, at stimulating the conditions for additional facilities-based competition—the so-called "ladder of investment."[281] The effectiveness of these regulations to induce additional facilities-based competition has been called into question, especially when it comes to next-generation access networks.[282]

Moreover, the ladder of investment theory never adequately coped with the illogic of government regulation-induced costly duplicative "overbuilding" investment simply for the purpose of spurring competition. Indeed, competition in high-fixed cost industries such as telecommunications is not an unalloyed good—a smaller number of providers can more efficiently provide robust service at a lower cost.[283] A market can of course have too few competitors, resulting in monopoly prices or reduced output. But it can also have too many, resulting in fragmentation and duplication of resources. Considering the trade-offs inherent to a mandatory wholesaling regime, and little evidence of success for the ladder of investment, the Commission should lean toward relaxing wholesale access regulations, especially in markets with at least two fixed broadband providers. This is especially prudent if EU nations and localities put in place 5G-friendly policies, as 5G appears to be a viable competitor to fixed, wired broadband, as Verizon is showing in places such as Sacramento, California—a territory where they do not provide fixed wireline service, such as FIOS.

Appropriate access regulations are likely to stimulate investment as new entrants and incumbents alike fight to gain market share they can more easily see a return on. The facilities-based competition focus in the United States has seen more broadband investment and enjoys high-performance networks, despite the high cost of serving relatively low-population densities and detached, single-family suburbanized homes.[284] Scholars estimate that if the EU14 mobile network operators invested the same amount per capita as their U.S. counterparts, total annual capital expenditures would be $27 billion higher by 2020.[285] Their study concluded that "ex post regulation and competition policy are better aligned [to achieve successful 5G service in Europe] than traditional forms of ex ante regulation."[286]

5G will almost certainly accelerate wireless and wired competition, with 5G wireless services functionally substituting for fixed broadband connections to homes. Wireless services are a dynamic, competitive success story, and exactly which direction they will take next is difficult to predict. The long-term trends are clear, however: Services are converging over the IP platform, with the particular access technology—wired or wireless—less relevant, with everything going wireless for at least the last hundred feet or so. Wireless networks need more backhaul—to look more and more like wired networks—while cable networks continue to deploy Wi-Fi access points and explore wireless business models.

In addition to reforming wholesale regulations, and allocating more spectrum for commercial, mobile, 5G services, there are opportunities for the Commission to help streamline the deployment of 5G. Wireless networks are increasingly relying on small cells, especially for extremely high-frequency spectrum above 24 GHz. Arcane bureaucracies that control rights of way and historic preservation have an outsized impact on the deployment of this infrastructure-heavy wireless architecture. **The Commission should help reduce administrative burdens and lower costs of deployment for infrastructure such as small cells by reexamining existing regulations and processes designed for yesterday's much larger macro towers, and coaxing local authorities to update their equipment-siting requirements.**

The Commission should not look to regulate over-the-top providers with legacy requirements applied to telecommunications providers.

5G and other next-generation networks and services will increasingly rely on differentiated and flexibly provisioned network services.[287] Network slicing offers the ability to create logical circuits with specified performance requirements, potentially in a way that approaches prohibitions under the Body of European Regulators for Electronic Communications' recommended net neutrality regulations.[288] **European policymakers should continue to evaluate the benefits of differentiated network services and whether existing net neutrality regulations impede innovative new applications.** On the other side of the coin, neither should the Commission look to regulate over-the-top (OTT) providers with legacy requirements applied to telecommunications providers. The goal should be functional facilities-based competition that allows relaxed regulatory requirements and encourages network operators to expand the scope of their business models and effectively compete with OTT services—a leveling down of the playing field that enables dynamic competition by all firms.

Technology/Sector/Firm Policies

While the right business climate and policies to increase the quality and quantity of firm resources can help spur CAS development and adoption, they are not sufficient for success, much less global leadership. One reason is, unlike the last digital waves (Internet/e-commerce/search and social media/cloud), wherein adoption rates were very fast, in part because adoption involved relatively straightforward actions by producers and consumers, the next CAS wave will likely be longer and more complicated, in part because much of it involves business-to-business (B2B) transactions and more-complicated coordination challenges between original equipment manufacturers (OEMs), suppliers, and customers. For these reasons, governments need to embrace technology-, industry-, and firm-specific

ICT policies. One key place for Europe to double down on this is public-private partnerships in specific ICTs and industries.

The Case for ICT Public-Private Partnerships

The EU would be well advised to take advantage of core European competencies, particularly its political and institutional ability to engage in smart public-private partnerships (PPPs). As ITIF has shown in its series *Explaining International IT Application Leadership*, the United States lags in many IT application areas that involve chicken-or-egg dynamics wherein innovation requires complementary action at the same time, in large part because of the lack of an overall government strategy.[289] Unlike in China, it is an uphill battle in the United States to enact proactive ICT PPPs, in large part because of a political aversion to anything that smacks of "industrial policy" or "picking winners and losers."

But without such PPPs, in many areas, digital transformation will lag behind the technology opportunity. This is largely because the systemic advances of many ICT applications require coordinated action at the same time. Individual firms acting on their own, even if they are large and committed, can often be stymied when systemic application is brought about. A case in point is digital signature/E-ID technology: Users do not sign up for digital IDs unless there are applications they can use them for and vice versa. In areas such as health IT and digital signatures, some European countries lead the world because they have embraced digital public-private partnerships. Europe has real opportunities in areas such as smart cities, the Industrial Internet of Things (i.e., Industry 4.0), health IT, smart transportation, the smart grid, digital IDs, and many other areas. **EU policymakers should chart out steps articulating how the EU can help member states drive these and other application areas through smart public-private partnerships.**

Technology Strategies

Europe should have strategies for deployment of key, next-wave digital enabling technologies, such as Internet of Things, artificial intelligence, blockchain, and digital IDs. Overarching all of these particular strategies is the imperative that all EU governments become significantly better customers of existing and emerging ICTs. By being robust and smart users of ICTs, EU governments can help expand markets for technology while at the same time better and more cost effectively accomplishing government missions.

Moreover, it becomes easier to know whether and how to regulate technologies when governments are advanced and sophisticated users. However, overall, governments are falling farther behind the leading private-sector players when it comes to creating digital-first organizations. **The Commission should lead an effort to help member states become lead adopters of emerging CAS technologies.** This could include, for example, convening national government chief information officers (CIOs) around particular issues and technology opportunity areas. It could also identify and chart best practices in the adoption, purchase, and use of a variety of emerging CAS technologies, including new models.

The Internet of Things

The Internet of Things offers many opportunities to grow the economy and improve quality of life. Just as the public sector was instrumental in enabling the development and deployment of the Internet, it should play a similar role to ensure the success of the Internet of Things. Because many opportunities to use the Internet of Things are strongly tied to areas of public-sector activity (such as health, environment, transportation, defense, and city management), the EU needs to ensure it has a strategic policy to take full advantage of the Internet of Things and overcome market failures, regulatory challenges, and issues of equity.[290] An Internet of Things technology strategy should encompass funding, such as large-scale pilot projects and national challenges; convening and planning, such as to form industry partnerships to deploy sensor networks across multiple jurisdictions and develop industry-led standards for security; government-agency actions to deploy smart technologies within the public sector; regulatory actions, such as to allocate licensed and unlicensed spectrum for connected devices and modernizing regulatory processes for connected medical devices; and trade policy issues, such as ensuring the free flow of data and resisting nation-specific technology standards.

Artificial Intelligence

The EU should ensure it is a lead adopter of AI across important industries.[291] The Commission is already taking important steps in this direction.

The European Commission adopted its Communication on Artificial Intelligence for Europe in April 2018, which explains its plans to boost technical capacity and to spur public- and private-sector AI adoption, and has outlined its planned activities to support AI, such as by increasing investments and improving research centers, through 2020.[292] The Commission aims to design a strand of AI that upholds fundamental European values and rights, and promotes investment in ethical-by-design AI. For this purpose, it has established the European AI Alliance, a public forum designed to foster discussion about the impacts of AI.[293] And in June 2018, the Commission established the High-Level Expert Group on Artificial Intelligence (AI HLEG) with 52 appointed experts from industry, civil society, and academia to support implementation of the Communication on Artificial Intelligence.[294]

In November 2018, the Commission launched a call for proposals from at least eight member states to establish 30 Digital Innovation Hubs (DIHs) focused on AI.[295] Selected DIHs will support particular regions and industries in digitization through the use of AI, and focus on using AI in various sectors such as medical technologies, digital manufacturing, and digital design.[296] The group's mission includes identifying mechanisms promoting technology that delivers on European values. Intentions are not to regulate—yet.[297]

In addition, the Commission is currently assessing with member states all legislation that can be affected by AI, such as the Product Liability Directive and the Machinery Directive. There is no rush to legislate more or modify legislations. Evaluations aim to both potentially formulate recommendations to fix inconsistencies, and ensure existing legislations are fit for purpose and continue to offer legal certainty in the value chain.

With Horizon Europe, the next Framework Program for 2021–2027, research funding for AI will increase significantly relative to the previous program, Horizon 2020. In addition, this time, AI is outlined as a specific research topic, along with robotics. The proposal allocates €15 billion to this cluster. The Commission also created the Digital Europe program, a new investment scheme in which €2.5 billion will be directly allocated to AI. An additional €700 million will be invested in advanced digital skills training and education, which can be seen as indirect investment in AI.[298] Lastly, one remaining objective of the Commission is to increase public and private investment in AI by at least €20 billion through 2020.[299]

By being robust and smart users of ICTs, EU governments can help expand markets for technology while at the same time better and more cost effectively accomplishing government missions.

One particular challenge for the EU is ensuring small and medium-sized enterprises (SMEs) can successfully adopt AI. Achieving this should involve a threefold strategy. First, **EU member states should develop local AI skills training by developing partnerships with local universities and industry, including through data science "boot camps."** Second, EU member states should ensure SMEs that may not be able to hire AI experts full-time are able to hire companies providing these services. Achieving this will require training for these companies on AI capabilities and opportunities, as well as on how to successfully manage these types of projects and contracts. Finally, the EU should encourage the development of more off-the-shelf AI tools that do not require extensive knowledge about AI, but instead require only baseline programming or analytical skills.

There are particular areas wherein Europe could have natural advantages, should it be able to overcome its political and institutional hurdles. For example, because most health care in European nations is provided by public health authorities, the EU has an opportunity to amass extremely large datasets on patients and outcomes.

Blockchain

Blockchain refers to a shared, digital ledger that catalogs transactions as they occur in chronological order, using cryptography and public records to validate transactions. Blockchain technology enables safer, more efficient, and easier data exchange and processing. Abuse of this technology is difficult because every transaction is transparent and controlled by several computers. With regard to blockchains, **governments have a role to play in taking a lead and giving direction to technological developments at an early stage.** A good example of this is the establishment of the National Blockchain Coalition (Nationale Blockchain Coalitie) in the Netherlands, through which the Dutch government cooperates with knowledge institutions and companies with various perspectives (i.e., innovation, legal, knowledge, skills, etc.) to stimulate the application of a specific technology and thus seize opportunities for innovation. This coalition lays the foundation (with building blocks such as digital identities, security, legal frameworks, etc.) for the large-scale rollout of blockchain technology with parties from the logistics, energy, financial services, and ICT sectors as well as the Dutch government. Based on five cases, an exploratory study is being carried out under the supervision of the Research and Documentation Centre (Wetenschappelijk Onderzoek- en Documentatiecentrum, or WODC, part of the Ministry of Justice and Security) into the scope offered by legal frameworks for exploiting the opportunities of blockchain technology, mitigating possible risks, and exploring points requiring attention for future legislation. The advantage of this approach is, at an early stage, attention is also paid to public values such as privacy and security.

Digital IDs

Some EU members, in particular Estonia, have made great progress in ensuring widespread rollout and adoption of electronic identification. These digital ID systems allow individuals to prove their identity, or attributes about their identity, to information systems. **The Commission should encourage each member state to offer an electronic ID to residents who desire one. It could go even further and require all national governments to offer each of their citizens an electronic ID when they apply for their paper passport.** These IDs could be offered as standalone products, such as smartcards or software certificates for mobile phones, or on existing identification documents, such as passports.[300] These IDs should be more than just links to different information that let people prove with a high degree of certainty who they are, they should be encrypted, secure IDs backed by the government—just as national IDs and passports are. As part of this effort, Europe should continue to make European digital ID systems fully interoperable.

Industry Strategies

One of the key defining aspects of the next ICT wave is it will become more central to transforming a wide range of industries. The mainframe era enabled mostly large corporations in a few industries (e.g., finance, insurance, advanced manufacturing) to process information more effectively. The personal-computer era democratized computing, allowing more industries and a wider array of firms, including SMEs, to use the technology to better process information and cut costs. With the advent of the Internet, social media, and the cloud, virtually all firms have been required to develop an Internet presence to enable sales and information sharing (as well as a social media presence if for no other reason than for better marketing)—and over the last decade, more firms have adopted the cloud to cut IT costs and streamline operations.

The next CAS phase will be more transformative, with many industries using the technologies to generate massive amounts of information in order to improve processes, develop better product and service offerings, use autonomous systems and more powerful automation to dramatically cut production costs, and use smart algorithms to significantly improve, if not transform, offerings. Collectively, these technologies will enable industries to be transformed to become "smarter" (e.g., smart agriculture, smart construction, smart transportation, etc.). Some of that transformation will result from incumbents realizing that if they do not cannibalize their own business, as Harvard Business School Professor Clayton Christensen advises, then someone else will do it for them.[301] But even though more and more firms understand Andy Grove's aphorism "only the paranoid survive," the reality is a significant share of incumbent firms will be too slow to respond to the change. The forces of inertia will be too great. As a result, much of the change will have to happen from "gazelle" entrants—new firms with a passion for growing by disrupting existing markets—and from existing technology firms that see their future in using technology as disrupting existing industries (e.g., health care, financial services, education, transportation, etc.). If the competition policy and regulatory environments in Europe protect incumbents and make it harder for the new entrants (starts-ups and "big tech"), Europe will lag behind other regions in both the development of competitive CAS firms and the transformation of industries through CAS.

Regardless of where the transformation comes from—incumbents, new firms, or big tech—**Europe should focus on using existing programs and policies that affect particular industries to drive CAS transformation.** Increasingly, the focus should be less on digital per se and more on innovation through digital in industries and other areas: The agriculture sector needs to integrate digital, with DG AGRI taking the lead; financial services need digital integrated into the sector, with DG ECFIN taking the lead; transportation needs digital integrated into it, with DG MOVE taking the lead; etc. In other words, the job of digital transformation is far beyond DG CONNECT's alone.

The Commission should lead an effort to help member states become first adopters of emerging CAS technologies.

To improve the Commission's ability to implement a digital agenda more broadly, **each major directorate, especially those working in industry areas, should have a chief technology officer (CTO) whose job is to work to ensure that the directorates' policies are all aligned with CAS sector transformation.** Importantly, their role would not be that of CIO or internal IT director whose job is to manage a directorate's internal ICT systems. Rather, their task would be to craft and implement an innovation strategy as it relates to the emerging CAS technology system. EU directorates can drive innovation not only in their own programs and operations, but also in the broader sphere of the economy they influence. Yet few EU directorates have formal ICT-based innovation strategies. Every directorate should also develop a comprehensive ICT-based innovation strategy. This should cover not only how the directorates themselves will innovate internally, but more importantly, how they can spur innovation in the sectors of the economy they impact.

One other task for CTOs would be to identify ways EU start-ups can pilot technology and technology-related business models, thereby leveraging state-owned infrastructures, including in member states such as the postal system, electric grid, social security agencies, and other platforms.

Health IT

It is beyond the scope of this report to lay out a complete health IT strategy, but there are nevertheless a few areas the Commission should focus on. The first is to **enable the easy movement of health data across borders.** The second is to **identify EU-wide taxonomies for health information so applications can easily work with patients and patient data from all EU nations**. The third is to **provide incentives for all players in the health system to put their data in open-API formats,** with patients at the core in terms of granting permissions, so data can be easily consolidated into patient-centered health information applications. Patients should be able to view and manage personal data being stored in different places in one integrated application, and then securely share it with the health care provider of their choice. If the EU is looking for grand challenges, enabling this kind of system for every European citizen is such a challenge. Finally, such a system should be designed such that patients can easily opt in to share some or all of their health data with researchers seeking to improve medical care and support medical innovation.

Smart Manufacturing

Some EU nations, including Germany, have made considerable progress toward helping manufacturers become more digital. But more can and should be done. **The Commission should fund the establishment of an EU-wide version of America's Digital Manufacturing and Design Innovation Institute (DMDII).**[302] The DMDII, funded by the U.S. federal government and industry, serves as the United States' central hub for the development, showcasing, distribution, and transmission (especially to SMEs) of knowledge, tools, software, and expertise related to manufacturing digitalization. The Obama administration announced DMDII's formation in February 2014. It was granted $70 million in federal funding which, with additional 2-to-1 matching from companies, universities, and state and regional governments, has thus far received at least $140 million. In 2109, it received an additional $50 million from the Department of Defense. DMDII serves as a state-of-the-art proving ground for digital manufacturing and design that links information technology tools, standards, models, sensors, controls, practices and skills, and transitions these tools to America's design and manufacturing industrial base for full-scale application. DMDII works with firms of all sizes, including trying to assist SMEs in navigating their digital transformation journeys.

Another important policy tool to spur greater innovation in European manufacturing, including digital innovation, is if universities were more focused on manufacturing innovation. To do this, **the Commission should fund a network of M Universities.** Engineering departments at most EU universities have shifted to a science-based model of engineering that focuses more on publishing abstract scholarly papers than on working with private-sector firms to solve real-world problems. Moreover, more engineering students need to get hands-on experience with industry before graduation.

The Commission should fund a challenge grant of perhaps €20 million per year for five years to create a core of at least 20 universities that would brand themselves as manufacturing universities. Designated universities would have several responsibilities. First, they would be required to revamp their engineering programs much more around manufacturing engineering, with particular emphasis on work that is relevant to industry. This would include more joint industry-university research projects, more training of students that incorporates manufacturing experiences through cooperative education or other programs, and a Ph.D. program focused on turning out more engineering Ph.D.'s who would work in industry. These universities would view doctoral training as akin to high-level apprenticeships (as is often the case in Germany) and would not allow the conferral of a Ph.D. unless one has done some work within the industry. Likewise, criteria for faculty tenure would consider professors' work with in industry equally as much as their number of scholarly journal publications. In addition, business schools would focus on manufacturing issues, including management of production, and work closely with the engineering program. One can imagine a number of leading engineering universities in Europe readily transforming themselves to embrace this designation. These Manufacturing Universities would complement, not duplicate, any Commission-supported or national government-supported manufacturing institutes. This Manufacturing Universities proposal would work to ensure universities themselves function in ways that are more supportive of the EU manufacturing economy. This program could be modeled in part on a similar program in the United States that is just now being rolled out, called the Manufacturing Engineering Education Grant program.[303]

One of the key defining aspects of the next ICT wave is it will become more central to transforming a wide range of industries.

The Commission should also consider a program to provide incentives to large OEMs to partner with their smaller suppliers. The Commission could provide incentives for EU OEMs to help 10,000 SMEs become Internet of Things-enabled (that is, smart-manufacturing-enabled) within 10 years. The OEMs and Tier 1s (the suppliers that sell directly to OEMs) need to press their suppliers to upgrade their equipment (otherwise it is just not on the SMEs' radar screens) and support them in these efforts. The OEMs could host workshops/seminars to guide SME suppliers in digitalization strategies and on how explicitly to integrate digitally into supply-chain management systems. Federal incentives could take the form of grants for a certain number of suppliers. Also, related to this, the OEMs tend to want transparency regarding the parts flowing out from the suppliers, but the suppliers may not desire this, so there are issues regarding who controls and secures the data. By incentivizing OEMs to collaborate with SMEs on these questions, approaches that add value for both parties and frameworks set up with regard to data ownership issues can be found.

Likewise, the Commission should consider funding, in partnership with national governments, regional digital manufacturing hubs and pilot digital manufacturing centers/test beds that can scale. For instance, DMDII's Digital Capability Center and Future Factory Line represent compelling, practical, real-world exemplars showcasing the potential of manufacturing digitalization. But they are one-offs, and lack scale across the United States, which is why ITIF has called on the U.S. Congress to provide funds to replicate these pilot digital manufacturing centers/test beds to connect with smaller manufacturers across the country, such as by embedding them in national laboratories, universities, and regional community colleges. Essentially, manufacturers need to be able to "kick the tires" of smart manufacturing systems to see how they actually work, and understand what specific technologies are involved. At the same time, they need workers with new skills, including both engineers and technicians. Similarly, the Commission should create a competitive grant program that enables technical colleges and universities to bid to serve as digital manufacturing hubs for their regions. To qualify for funding, these institutions would need to obtain a match from either national or local governments of at least 1 to 1 in order to continue receiving at least some funding from industry partners/clients. Funding for such centers should be for at least five years, conditional on center performance.

The Commission should make sure there is an online benchmarking tool for manufacturing digitalization available for all EU SMEs. In 2015, the United Kingdom launched the Mayfield Commission study to find the causes of, and propose solutions to, the "large and widening productivity gap that exists between the UK and leading advanced economies." One of the outcomes of the study has been the launch of the United Kingdom's Be the Business website, an online repository of inspiration, tools, and resources for businesses to get started on their improvement journey. The website includes an online productivity benchmarking tool that allows U.K. SMEs (with at least 10 employees) to assess where they stand vis-à-vis peers, on a sector-specific basis, in terms of challenges such as digitalization; future planning; employee engagement; and leadership. That is one example to draw from, but it has also been suggested that **the Commission develop such a Digital Manufacturing Readiness Assessment Tool with the ability to benchmark a firm's results against anonymized data from similar peers in the manufacturing sectors in which they compete, and make it available in part online.** This would give EU SMEs the ability to make real-time assessments about how well they are progressing toward manufacturing digitalization, and suggest useful routes toward improvement.

Digitally-Enabled Cleaner Energy Systems

The next IT-enabled innovation wave of technologies holds great potential to facilitate the transition to clean energy. European policy will strongly shape how fully energy systems realize this potential. Whether energy data is accessible and usable, whether opportunities to start and build digital energy businesses are available, and how well smart infrastructures (including clean energy systems) are integrated at the urban and regional levels, including in buildings and industrial facilities, are among the key variables policymakers will influence, either by taking action or failing to do so. Given the United States' lagging position in this area, this represents a potential important growth opportunity for the EU, which it can facilitate through both increased funding and support for national-level regulatory changes to enable digital energy innovation.

Transportation

Surface transportation is poised to be transformed by the next wave of information technology. **DG Move should be actively working to encourage member states to embrace smart transportation systems and share best practices from around not only Europe, but the world.** This should include making sure digital technologies receive much greater priority in all transportation infrastructure funding. The Commission should also fund innovative deployments of smart transportation technologies in member states.

Smart Cities

Many European cities are striving to become smart cities—cities capable of collecting and analyzing vast quantities of data to automate processes, improve service quality, provide market-signal feedback to users, and make better decisions.[304] While local governments can and should manage much of this transformation, the EU and its member states have an important role to play in accelerating and coordinating the development of smart cities. Indeed, the long-term success of European smart cities will likely depend on the extent to which the EU and member states support smart cities development to address issues such as a lack of focus on smart infrastructure, interconnectivity between cities, underdeveloped communities of practice, and security and equity.

European policymakers should ensure the benefits and costs of CAS are more widely debated in Europe, and simplistic, negative narratives should not become accepted wisdom—which is already very close to happening.

The EU can support the development of common R&D for smart cities, including for key technical challenges such as cybersecurity, demonstration projects for smart city applications, and the development of common applications and tools that have use in multiple cities. In particular, **the EU should develop an EU Smart City App Store—a common repository of approved commercial applications and open-source code—that other cities can adapt and reuse**. The EU can also develop policies and common standards for smart city technologies that encourage interoperability and data sharing, foster inter-city learning on smart city strategies, and encourage additional pilot projects, including those that address the needs of underserved communities.

Finally, for all of these technology and industry areas related to CAS, much of the innovation will occur in member states. **The Commission should establish a competitive pilot-scale programs to support member states that establish truly innovative CAS-related policies, programs, and projects.** And for those policies, programs, and projects that are successful, the Commission should work to help all governments in the EU adopt them.

Culture and Institutions

While framework, technology, and industry policies are important for spurring CAS transformation, so too are culture and institutions.

Culture

There is much literature on how to establish a culture of innovation within companies.[305] But there has been much less written about how nations can create a culture that is conducive to innovation. There are some general themes, however, such as a culture that views science and engineering as positive, and a culture that supports risk-taking and entrepreneurship.

The broader-based embrace of the precautionary principle in Europe compared with many Asian nations and the United States arguably makes innovation harder in Europe. ITIF wrote about this extensively in its report *Comparing American and European Innovation Cultures*.[306] One thing the report found is Europeans appear less willing to take risks than Americans and Chinese. For example, when asked about their views on the statement: "One should not start a business if there is a risk it might fail," just 26 percent of

Americans agreed, versus 49 percent in the EU-25.[307] When asked, "In general am I willing to take risks?" 39 percent of Americans strongly agreed, compared with 16 percent in the EU27 nations (and 18 percent in China).[308]

It is not readily clear how to change cultural attitudes affecting innovation. One factor is the presence of external threats. In his book, *The Politics of Innovation: Why Some Countries Are Better Than Others at Science & Technology*, Mark Zachary Taylor stresses the importance of what he calls "creative insecurity" and defines as, "the positive difference between the threats of economic or military competition from abroad and the dangers of political-economic rivalries at home."[309] Such insecurity leads nations not only to take the politically difficult step of investing for the future, but also to challenge incumbent interests that might stand in the way of innovation. He points to this as a reason why nations such as Israel, Taiwan, and the United States have enjoyed innovation success. There is not much Europe can do about this objectively, but the apparent pullback of the American security shield Europe has lived under for more than 70 years, plus the emergence of China as a technology power, can and should be used to ratchet up the urgency of innovation. This might also spur more spending on defense in Europe, which, depending on how it is designed, could yield important benefits for innovation.

With regards to the precautionary principle, **the Council should lead a dialogue in order to at least raise the issue that Europe would be better off it operated on the innovation principle, not the precautionary principle, when it comes to future ICT.** In other words, Europe should proceed on the assumption AI and other CAS technologies will be fundamentally good, and while they will present some risks—as every new technology does—policy should focus on addressing risks if and when they arise, and not preemptively regulating the technology in ways that slow its adoption. Living by the innovation principle also means understanding that CAS technologies will involve both Type I and Type II errors, which is to say they will produce some errors, but will also reduce or even eliminate many others.

This will be particularly important now, when the CAS transition is viewed by many in Europe, including many pundits and activists, as a threat to jobs, fairness, dignity, and even human lives. In fact, a major barrier to a whole-hearted embrace of the CAS revolution comes from the growing narrative from a set of vocal techno-Jeremiahs that this technology-driven productivity acceleration is something to be feared and slowed, as it will eliminate a massive number of jobs, leading to mass dislocation and even a jobless future. Nothing could be more wrong, for the simple reason technology spurs productivity, which in turn spurs more spending, thereby creating more jobs.[310] European policymakers should ensure the benefits and costs of CAS are more widely debated in Europe, and simplistic, negative narratives should not become accepted wisdom—which is already very close to happening.

Also, developing a more entrepreneurial culture is not something a region or nation can do overnight or with the passage of legislation. But it is something that at least could be amenable to change by focused actions. Europe can continue to expand its promising efforts to support and build local technology entrepreneurial hubs and ecosystems. **As such, the Commission should expand support for EU universities and colleges to create or expand entrepreneurship education programs.** Here, the United States is a model. According to the Kauffman Foundation, in 1985, there were about 250 entrepreneurship courses offered across all college campuses in the United States. By the late 2000s, more than 5,000 entrepreneurship courses were offered.[311] In 1975, U.S. colleges and universities offered around 100 formal majors, minors, and certificates in entrepreneurship. By 2006, they offered 500.[312] EU programs could be modeled on successful U.S. programs such as Stanford University's StartX program or Johns Hopkins University's Fast Forward program.

The Commission should also consider providing challenge grants to universities to reform university engineering curricula toward more project-based learning and entrepreneurship. One model is the Olin College of Engineering in Massachusetts, which reimagined engineering education and curricula to prepare students "to become exemplary engineering innovators who recognize needs, design solutions, and engage in creative enterprises for the good of the world." Olin's results have been impressive. Its new method of teaching engineering has been widely praised among engineering firms, and on a per-student-graduated basis, Olin graduates start more new businesses than even MIT graduates. Olin is a good model for how the EU can transform its colleges into entrepreneurial factories, while encouraging the development of completely new schools based on the needs of the current workforce.

U.S. universities do more than teach courses on entrepreneurship and innovation, they provide extensive innovation support. In 2012, about one-third of business incubators were located at universities.[313] This relates to another factor, which is for the Commission to provide stronger incentives for EU universities to become start-up and commercialization friendly, including by such actions as providing students with entrepreneurship leave if they want to put their education on hold to start a business. Universities should define an entrepreneurial leave policy for undergraduate and graduate students in which students could retain full-time student status for one to two years while launching their own company. **EU agencies should encourage EU universities to adopt a policy whereby any graduate or postdoctoral student on an assistantship, fellowship, or other form of government support can petition for a no-cost extension to take an "entrepreneurial leave" for one to two years to start a company.**

Institutions

One of the defining characteristics of the CAS transformation is, if it is to be successful, more organizations will need to transform their business models, including governments and nonprofits. In this regard, **one of the key roles for the Commission will be to support innovative new organizational models in Europe, in areas such as health care, transportation, education, and others.**

At the same time, Europe needs to ensure its policies overall are more oriented toward enabling ICT-led productivity. 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 noted, scholarly literature clearly shows there is no negative relationship between higher productivity and job growth.

To effectively identify and analyze productivity-enhancing policies, Europe should consider establishing a dedicated productivity agency or Commission. Europe had a European Productivity Agency in the 1950s, which quickly became the OEEC Productivity and Applied Research Committee—which was eliminated in 1962 with its functions moved to other agencies.[314] While the Commission encourages the establishment of National Productivity Boards, many key issues can only be addressed at the EU level.[315] Moreover, the focus of the boards in many nations is often beyond productivity and too often on macroeconomic issues, as opposed to industry-, technology-, and firm-specific productivity issues.[316] As such, **the EU should form a new European Productivity Agency to**: 1) study how technology can drive productivity growth within European industries; 2) identify specific policies, as opposed to broad-based macroeconomic and framework policies, to spur faster technology-based productivity; and 3) act as a champion within the EU for stronger productivity policies, specifically, and productivity itself more broadly. This is particularly critical as there is a growing and false narrative on both sides of the Atlantic that productivity not only does not benefit workers, but that it harms them by killing jobs, reducing wages, and spurring inequality. This narrative is wrong.[317]

CONCLUSION

Europe has a significant opportunity to make major strides in the next wave of digital transformation, but will need to adopt a forward-looking policy perspective that focuses foremost on the benefits the next generation of digital technologies can bring to Europe's economy and society. In particular, Europe should leverage its distinct strengths in areas such as collaborative public-private partnerships and advanced industrial engineering to position itself to be a global leader in the coming CAS transformation. While Europe should be attuned to potential digital harms, it should remember that, in total, these are well-outweighed by digital benefits, and manage its digital policymaking framework accordingly.

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