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"How the Innovation Economy Leads to Growth"
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Chairman Paulsen, Ranking Member Heinrich, and members of the Committee. Thank you for the opportunity to testify at this hearing. I am the Vice President of Governance Studies and Director of the Center for Technology Innovation at the Brookings Institution and the author of several books on innovation: *The Future of Work: Robots, AI, and Automation* (Brookings Institution Press, 2018), *Going Mobile: How Wireless Technology Is Reshaping Our Lives*, (Brookings Institution Press, 2015), *Digital Schools: How Technology Can Transform Education* (Brookings Institution Press, 2012), *The Next Wave: Using Digital Technology to Further Social and Political Innovation* (Brookings Institution Press, 2011), *Digital Medicine: Health Care in the Internet Era* (Brookings Institution Press, 2009), and *Digital Government: Technology and Public Sector Performance* (Princeton University Press, 2005). My books have won awards and been translated into Chinese, Japanese, and Korean.

The federal government plays a vital role in encouraging innovation, along with industry, universities, and non-profit organizations. At a time of considerable disruption during the shift to a digital economy, the United States should take six steps to increase economic growth and make sure it does not fall behind other leading nations. These actions include:

- increasing federal R&D,
- addressing critical needs in artificial intelligence and data analytics,
- developing a national data strategy,
- promoting STEM education,
- investing in physical and digital infrastructure, and
- improving digital access.

Increasing Federal R&D

The United States has a vibrant private sector that has made our country the leader in many aspects of technology innovation. It is home to outstanding universities, national labs, private companies, Nobel Prize winners, scientists, and entrepreneurs. The quality of these individuals and organizations has put America at the forefront of the innovation economy.

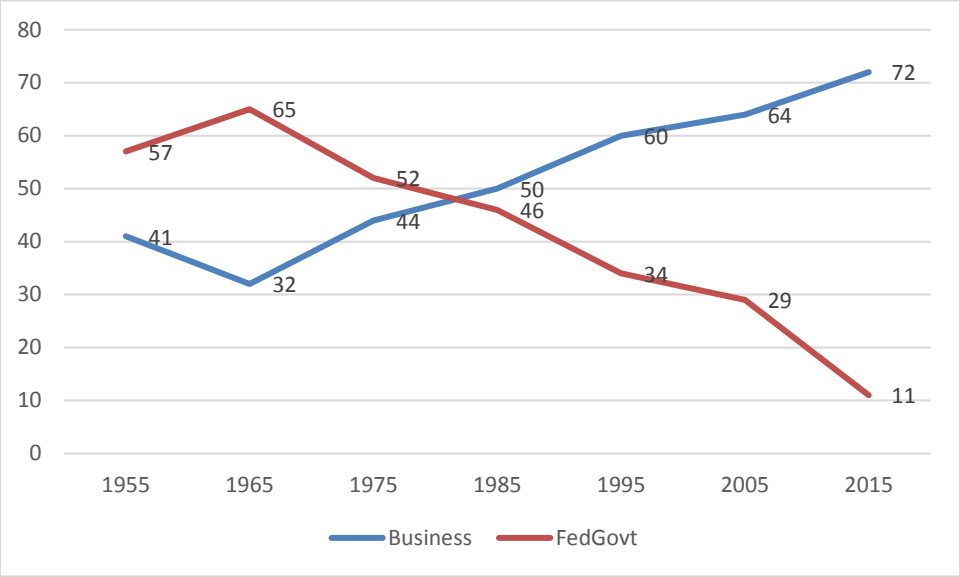
But these strengths do not mean the federal government should do little to facilitate the innovation economy. The internet represents one of the most successful government investments of all time owing to its origins as an Advanced Research Projects Agency communications tool known as ARPANET. NASA's space program gave us global positioning systems, 3-D maps, and imaging systems, among other benefits. The interstate highway system connected people and businesses around the nation. The success of these and other federal programs laid the groundwork for the innovation economy and demonstrates the constructive roles Congress and the President can play.

One of the most important federal roles is in support of research and development (see Table 1). Overall, America devotes $495 billion to R&D. Private industry remains the largest funder of R&D at $355.8 billion (or 72 percent of the total), followed by higher education at $64.6 billion (13 percent), the federal government at $54.3 billion (11 percent), nonprofit organizations at $19.7 billion (4 percent), and state and local government at $600 million.[1]

Table 1 Sources of R&D Spending in the United States (as of 2015)		
	Dollars	**Percent**
Business	$355.8 billion	72%
Higher Education	64.6	13
Federal Government	54.3	11
Nonprofit Organizations	19.7	4
State/Local Government	0.6	0
Total	$495 billion	100%
Source: U.S. National Science Board, "Science and Engineering Indicators," 2018.		

Over the past few decades, though, the federal percentage has dropped considerably. Figure 1 shows the changes in percentage of total R&D spending by business and the federal government between 1955 and 2015. In 1955, the federal government provided 57 percent of R&D expenditures compared to 41 percent from businesses. Today, only 11 percent of overall R&D comes from the federal government, while businesses provide 72 percent.[2]

Figure 1 Changes in Percentage of Total R&D Spending by Business and Federal Government, 1955-2015

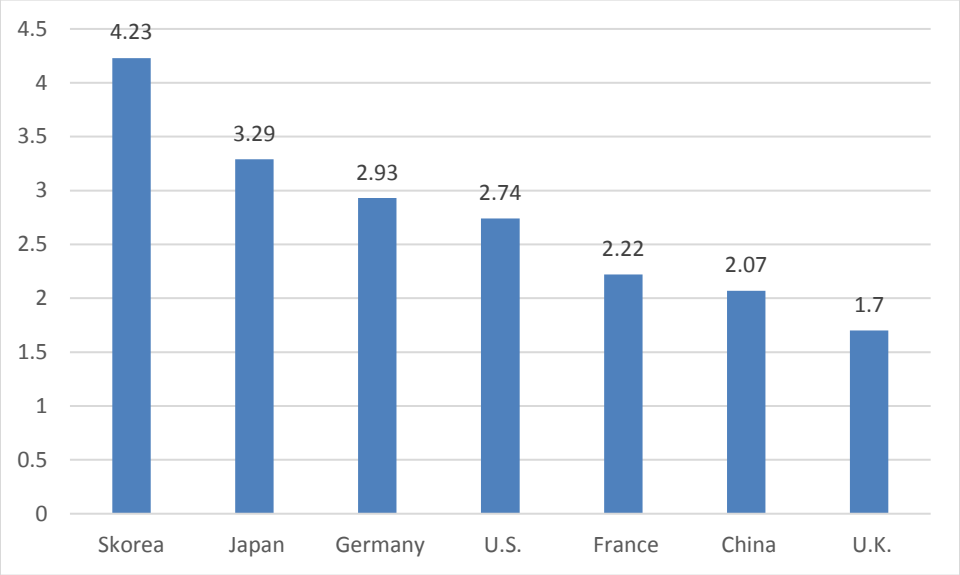


Source: U.S. National Science Board, "Science and Engineering Indicators," 2018, Appendix Table 4-1.

Part of the danger of relying on the private sector for three-quarters of R&D spending is its vulnerability to macroeconomic cycles. When the economy weakens, one of the first things companies do is slash their R&D support in order to reduce short-term spending. Important strategic priorities can be lost through the disparate decisions of individual firms. Boosting federal R&D spending would make research activities less dependent on the business cycle and the choices of particular companies.

There also are issues in terms of failing to keep up on international competitiveness. As shown in Figure 2, the United States spends 2.74 percent of Gross Domestic Product on R&D. This is less than the 4.2 percent spent by South Korea, 3.29 percent by Japan, and 2.93 percent by Germany, but more than the 2.22 percent for France, 2.07 by China, and 1.7 by the United Kingdom.[3]

Figure 2 Percent of GDP Spent on R&D by Leading Countries, 2015



Source: U.S. Science Defense Board, "Science and Engineering Indicators," 2018, Figure 4.7

Even though China falls behind the United States in percent of GDP spending on R&D, it is increasing its R&D spending at a rapid rate. Between 2000 and 2010, for example, it had average R&D spending increases of 20.5 percent a year and from 2010 to 2015, it boosted its R&D expenditures by 13.9 percent a year. For the time between 2000 and 2015 as a whole, China accounted for 31 percent of the world's R&D increase (or a total of $376 billion).[4] With these kinds of increases, the United States has to be careful not to fall behind our competitors.

Addressing Critical Needs in AI and Data Analytics

One area requiring more extensive federal support is artificial intelligence and data analytics. According to Greg Brockman, the co-founder of OpenAI, the U.S. federal government invests only $1.1 billion in non-classified, AI technology.[5] That is far lower than the amount being spent by China or other leading nations in this area of research. At its 19th Party Congress, for example, China set a national goal of investing $150 billion in AI and becoming the global leader by 2030.[6]

Already, China is making rapid strides in AI. With its large population and willingness to gather information from video surveillance, financial records, social media posts, travel movements, and the like and the technical capacity to integrate that information in comprehensive data bases, China is poised to make quick advances if the United States does not increase its funding of unclassified research.

America's shortfall in this area is worrisome because our country risks falling behind on technology innovation. As Brookings President John Allen and I note in our recent paper, AI is the transformative breakthrough for coming decades that will dictate leadership in national security, economic development, resource management, transportation, finance, and healthcare.[7]

Falling behind in this sector will doom our country to diminished economic performance and put the nation at risk in terms of national security.

At the same time, if we boost our AI investments, there are likely to be substantial benefits and the investment will pay for itself many times over in economic and social benefits.[8] A project undertaken by PriceWaterhouseCoopers estimated that "artificial intelligence technologies could increase global GDP by $15.7 trillion, a full 14%, by 2030."[9] That includes advances of $7 trillion in China, $3.7 trillion in North America, $1.8 trillion in Northern Europe, $1.2 trillion for Africa and Oceania, $0.9 trillion in the rest of Asia outside of China, $0.7 trillion in Southern Europe, and $0.5 trillion in Latin America.

A McKinsey Global Institute study of China meanwhile found that "AI-led automation can give the Chinese economy a productivity injection that would add 0.8 to 1.4 percentage points to GDP growth annually, depending on the speed of adoption."[10] Although its authors found that China currently lags the United States and the United Kingdom in AI innovation, the sheer size of its AI market gives that country tremendous opportunities for pilot testing and development.

Developing a National Data Strategy

Data analytics have tremendous potential to transform public and private sector decision-making.[11] By providing analysis of information in real-time, analytics speed up the feedback loop and enable administrators and policymakers to see what data patterns are emerging overtime. So-called "big data" make it possible to study different areas for insights regarding student performance, health care, energy efficiency, national security, and public sector performance. Rather than rely on infrequent assessments, analysts can determine what is happening in real-time and what actions are associated with the most effective results.

The key to getting the most out of AI, though, is having a "data-friendly ecosystem with unified standards and cross-platform sharing."[12] Data that are accessible to the research community is a prerequisite for successful AI development. According to a McKinsey Global Institute study, nations that promote open data sources and data sharing are the ones most likely to see AI advances. In this regard, the United States has a substantial advantage over China. Global ratings on data openness show that U.S. ranks 8th overall in the world, compared to 93 for China.[13]

Yet right now, the United States does not have a coherent national data strategy and much of the digital data are not available to researchers. There are few protocols for promoting research access or platforms that make it possible to gain new insights from digital information. It is not always clear who owns data or there are no uniform standards in terms of data access, data sharing, or data protection. This lack of access limits innovation and system design as AI requires data to test and improve its learning capacity.[14]

There are a variety of ways to improve data access.[15] One is through voluntary agreements with companies holding proprietary data. Facebook, for example, recently announced a partnership with Stanford economist Raj Chetty to use its social media data to explore inequality.[16] As part of the arrangement, researchers were required to undergo background checks and access data from secured sites in order to protect user privacy.

Google long has made available search results in aggregated form for researchers and the general public. Through its "Trends" site, scholars can analyze topics such as views about democracy and perspectives on the overall economy. That helps people track movements in public interest and identify topics that galvanize the general public.

Twitter makes much of its tweets available to researchers through application programming interfaces (APIs). These tools help people outside the company build application software and make use of data from its social media platform. They can study patterns of social media communications and see how people are commenting on or reacting to current events.

In some sectors where there is a discernible public benefit, governments can facilitate collaboration by building infrastructure that shares data. For example, in the health area, the National Cancer Institute has pioneered a data sharing protocol where certified researchers can query health data it has using deidentified information drawn from clinical data, claims information, and drug therapies. That enables researchers to evaluate efficacy and effectiveness, and make recommendations regarding the best medical approaches, without compromising the privacy of individual patients.

There could be data partnerships that combine government and business data sets to improve system performance. For example, cities could integrate information from ride-sharing services with its own material on social service locations, bus lines, mass transit, and highway congestion to improve transportation. That would help metropolitan areas deal with traffic tie-ups and assist in highway and mass transit planning.

Some combination of these approaches would improve data access for researchers, the government, and the business community. As noted by Ian Buck, the vice president of NVIDIA, "data is the fuel that drives the AI engine. The federal government has access to vast sources of information. Opening access to that data will help us get insights that will transform the U.S. economy."[17] The federal government already has put over 230,000 datasets into the public domain and this has propelled innovation and aided improvements in AI and data analytic technologies.[18]

Promoting STEM Education

We know the innovation economy is key to long-term growth, but right now, there are too few Americans studying the STEM fields of science, technology, engineering, and math. There is a shortage of scientists, engineers, mathematicians, and data scientists, particularly among women, and these are the knowledge workers who will propel future economic growth and technology innovation. According to the National Center for Education Statistics, only 17 percent of American undergraduates earn a STEM bachelor's degree and 65 percent of them are male.[19]

Compared to other nations, the United States graduates a lower share of scientists and engineers. For example, 38 percent of Korean students earn degrees in science and engineering, compared to 33 percent for Germany, 28 percent for France, 27 percent for England, and 26 percent for Japan.[20] Owing to its large population, China is graduating the greatest number of STEM degree-holders. In 2016, for example, it graduated 4.7 million recipients of science, technology,

engineering, and math degrees, which far exceeds the 568,000 in the United States and 195,000 in Japan.[21]

To deal with our STEM needs, we need to hire new STEM teachers in K-12 schools and pay higher salaries to top STEM teachers. If we can interest young students in science and math, it will pay off in more STEM graduates down the road. We also need to attract women and minorities into STEM fields. Women start off their teen years with similar levels of interest in science as men, but their numbers drop off quickly in college and post-graduate work. And as the country moves towards becoming a "majority-minority" nation, finding ways to improve the racial and ethnic composition of the STEM workforce would help the United States enhance its talent pool.

Investing in Physical and Digital Infrastructure

Having fully functioning highways, bridges, and dams is vital for economic development. In its 2017 report, the American Society of Civil Engineers gave the United States a grade of D+ on infrastructure. Its experts reported that far too much of our physical transportation assets are deficient and they estimate it will take $10 trillion over the next decade to repair this infrastructure and thereby keep the country competitive internationally with other nations.[22]

Yet equally important is the digital infrastructure. According to recent Pew Research Center polls, 11 percent of Americans do not have access to the internet.[23] This ranks below South Korea, which has nearly universal coverage, and several Scandinavian and European countries, which provide coverage to most of their residents.[24]

High-speed internet infrastructure and digital connectivity serve as the backbones for many applications. For example, with high-speed broadband, patients can get second opinions from physicians geographically distant from themselves by emailing them radiology tests or magnetic resonance imaging scans (MRIs). Fast broadband also enables distance learning in education and smart energy grids for businesses and residences. Autonomous vehicles require artificial intelligence systems that instantly integrate LIDAR images, sensor data, and road conditions. In the entertainment area, Netflix recommends 25 megabits per second (mbps) of broadband speed for ultra-high definition television.[25]

Private companies are in the process to bringing 5G service to America so the future is bright in this area. Leading telecommunication firms are rolling out next generation services in selected cities this year and hope to offer nation-wide service next year. According to industry experts, 5G is expected to offer speeds that are "10 to 100 times faster" than 4G and will support new applications and more intelligent management of digital communications networks.[26]

But 5G requires the deployment of small cell towers to connect digital devices and the internet of things. In order to facilitate deployment, we need to streamline the approval process for building new small cell towers. Right now, every locality has different rules and processes for cell tower construction and this makes it difficult for private businesses to expand digital infrastructure in a timely and affordable manner.[27] This regulatory action should be a high priority for states and cities across the country so their slow approval processes don't delay innovation.

Improving Digital Access

It is crucial that all people share in the benefits of the innovation economy. Right now, there are significant disparities in access to digital technology based on income, race, and education. In addition, rural areas face particular challenges because their low population densities make it difficult to get high-speed broadband or reliable mobile service. According to the Federal Communications Commission, almost one-third of rural-dwellers lack access to high-speed broadband.[28] Having a digital infrastructure with glaring holes based on socio-economic status widens the gap between information haves and have-nots and exacerbates both racial and income inequality.

For underserved populations, there are a variety of actions that would increase mobile access and home broadband adoption. For example, digital literacy programs would train people on online applications that may be useful to them. Improved market competition also would help drive down consumer cost barriers that currently limit use for some people. And outreach programs could help bridge the digital divide based on age, race, gender, income, and education. With these proposed actions, consumers and small businesses would have better opportunities to gain the benefits of the digital economy.

We should at least make sure that schools, libraries, and hospitals in underserved areas have high-speed digital access so that these anchor institutions in communities provide access to those who do not have it at home. Even if particular individuals lack home access, having someplace in the community where they can go online is of great value. Having that kind of access would help needy individuals apply for jobs, access social service support, and keep in touch with family and friends.

A Critical Inflection Point

The United States is at a critical inflection point in its history. Our success in technology innovation and building some of the world's greatest internet platforms has positioned us for global leadership but also exposes us to risks in terms of the societal ramifications of digital disruption. As I note in my book, *The Future of Work: Robots, AI, and Automation*, not all our citizens are sharing in the benefits of the technology revolution and others are experiencing anxiety over shifts in business models, the nature of work, and financial prosperity.[29]

At this crucial moment, it is vital that we as a people and as a government invest in infrastructure, human capital, and research capacity because those are the things that will propel long-term growth and help us deal with the transition to a digital economy. One hundred years ago, our country grappled with a fundamental movement from an agrarian to an industrial economy. Our leaders stepped up to the plate, made important policy decisions, and set the country on the path to greatness in World War II and thereafter. We need strong leadership today so that we can retain our national leadership and assure peace and prosperity for generations to come.

Endnotes

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