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HOW THE INNOVATION ECONOMY LEADS TO GROWTH

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HOW THE INNOVATION ECONOMY LEADS TO GROWTH

WEDNESDAY APRIL 25, 2018

CONGRESS OF THE UNITED STATES,
JOINT ECONOMIC COMMITTEE,
Washington, DC.

The Committee met, pursuant to call, at 2:00 p.m., in Room 216, Hart Senate Office Building, the Honorable Erik Paulsen, Chairman, presiding.

Representatives present: Paulsen, LaHood, Handel, Delaney, Adams, and Maloney.

Senators present: Lee, Heinrich, Klobuchar, and Peters.

Staff present: Ted Boll, Colin Brainard, Connie Foster, J.P. Freire, Colleen Healy, Matt Kaido, Beila Leboeuf, Kim Corbin, Ricky Gandhi, Paul Lapointe, Alaina Flannigan.

OPENING STATEMENT OF HON. ERIK PAULSEN, CHAIRMAN, A U.S. REPRESENTATIVE FROM MINNESOTA

Chairman Paulsen. Alright, we will call the Committee hearing to order.

Good afternoon, and welcome to today's hearing on "How The Innovation Economy Leads to Growth."

The U.S. economy is not only growing, but it is also doing it faster. GDP growth is rising. Job creation is strong. Average wage growth is improving, and inflation remains low.

These long-awaited positive results stem from the decision to unleash America's most valuable economic asset: The American People. Tax and regulatory relief are allowing American families and main-street job creators more breathing room and to do more.

Contrary to those who believed that we are stuck at low growth, many economists expect as much as 3 percent GDP growth in 2018, and similarly strong growth in 2019. And to achieve this, Washington needs to stay out of the way so that individuals are free to figure out new ways to solve old problems. Such innovation is vital to sustaining our restored economic growth.

America has been a laboratory for invention since its inception, and it is that spirit that has led to our strength. A report by the McKinsey Global Institute in March of 2017, last year, finds that many advanced economies rely on productivity gains far more than increases in the labor supply to drive economic growth.

Folks in the private sector know this when they ask questions like: How can we serve more customers in one day? How can we complete more orders in less time? How can we produce a product with fewer passes of a machine?

Those questions are how innovation becomes the primary driver of productivity gains. And we know we are blessed to live in the United States for a variety of reasons, but among those blessings are our fellow Americans who have generated remarkable technologies to lift our standard of living, to expand our horizons, to support U.S. leadership in the world, and to grow our economy.

Not all economic systems are equally conducive to such path-breaking innovations. Every technological advancement of major economic consequence since World War II has come from the United States. And that is no accident.

As we will hear from our witnesses today, strong property rights, the rule of law, light regulation, and competition are critical conditions for visionary entrepreneurs and risk takers, dreamers and investors, and creators to generate the technological success that we have seen.

American inventors, main-street job creators, and the resourceful factory workers will continue to deliver amazing advances, but that is contingent on Washington allowing that to happen.

A brilliant idea or discovery is only the start. It has to be put into concrete form and developed. And from there, it has to be commercialized and disseminated throughout the economy before it actually boosts economic growth.

These steps can take a long time, depending on how they are taxed and regulated, or how antitrust law is applied. The highway to innovation is littered with potholes, traffic jams, and overturned vehicles. You can see this up close in my home State of Minnesota where an excise tax has threatened the innovative medical device industry, and could drive it away to other countries.

While the Federal Government has temporarily suspended this tax, innovators still face great uncertainty about their future.

Even more obstacles lurk along the path of international trade. Last year, this Committee held a hearing on digital trade. And the takeaway is that the United States leads in digital products and trade that rely on the internet.

Yet the freedom of the internet faces challenges abroad, and the United States must strive to protect it. To remain credible in this mission, the United States must generally promote and defend the long-held American principles of unencumbered international transactions and trade.

Every day has the potential for game-changing technological breakthroughs. Blockchain is an example of a technology at an early stage of development. Its potential for very wide application throughout the economy could be stifled by over-regulation.

And the United States has the opportunity to continue to be the champion of its Age of Invention, but only if we keep the engines of innovation running. We must protect the ability of our market economy to perform at its full potential at home and in global markets across the world.

I look forward to the testimony from our distinguished panel of witnesses today for clarity and for guidance on how innovation can drive economic growth and American prosperity.

Before I introduce our witnesses, though, I would like to now recognize our Ranking Member, Senator Heinrich, for his opening statement.

[The prepared statement of Chairman Paulsen appears in the Submissions for the Record on page 30.]

OPENING STATEMENT OF HON. MARTIN HEINRICH, RANKING MEMBER, A U.S. SENATOR FROM NEW MEXICO

Senator Heinrich. Thank you, Chairman Paulsen, for calling today's hearing on promoting innovation and accelerating economic growth.

Innovation drives economic growth and boosts wages. We need more of it, and we need innovation to be more broadly shared across regions.

Other countries are moving forward aggressively to promote innovation, to support advanced manufacturing, and to boost the productivity of their workforces.

To lead in the 21st Century, the United States must remain at the forefront of game-changing discoveries and create an ecosystem that supports innovation across the economy.

The Federal Government plays a key role in this, funding and conducting research and development, investing in human capital of our people, and in ensuring that we are making the necessary investments in a STEM workforce.

STEM education and R&D are two innovation anchors. We need to ensure that students everywhere have access to STEM pathways, and that starts with making sure that schools have the resources they need to recruit, train, and retain talented science and math teachers.

We need to expand middle-skills' pathways into emerging sectors, and make a college education accessible and affordable for all Americans, so that every student has the opportunity to benefit from tomorrow's innovations.

The Federal Government remains the largest funder of basic research. That research, which adds to our fundamental stock of knowledge, yet often would not be conducted without public investment.

This is the research that can help us solve the problems we do not yet know we even have. Basic research has driven major leaps forward, including mapping of the human genome, vaccines, breakthroughs in cancer research, and energy storage technology, and the creation of the internet, LASER, MRI, and GPS.

The knowledge gained through this research has significant spillover economic benefits: increasing productivity, creating jobs, and accelerating economic growth.

That is why it is encouraging that the recent Omnibus Agreement made significant investments in R&D. Investments in basic research increased by almost 10 percent over the previous year, its largest annual increase since the Recovery Act in 2009.

Promoting innovation also means extending already developed technologies like broadband to communities currently without access. Today, years after high-speed internet was first made available, 19 million rural Americans still lack access.

The private sector does not have the incentive to extend broadband to remote, hard-to-reach communities. The Federal Government must step in and fill that gap.

We also need smart policies that can help emerging industries grow. Targeted tax credits, competitive grants, and prize competitions are all levers that Congress can pull. The multi-year extension of the Wind Production Tax Credit is a good example. It is driving investment in wind farms in New Mexico and across the country.

Earlier this year, I toured the future site of the $1.6 billion Sagamore Wind Project in eastern New Mexico, which will be the largest wind production farm in our State's history, and create up to 300 construction jobs, and 30 full-time operations' jobs.

Programs like laboratory-directed research and development, LDRD, authorizing a portion of Federal labs' funding for cutting edge R&D are also quite vital.

At Los Alamos National Laboratory in New Mexico, LDRD researchers generally account for one-quarter of the lab's patents and peer-reviewed publications. Efforts to help commercialize technology developed at our national labs and research universities help to take a good idea and get it into production and out into the marketplace.

In New Mexico, we have seen how commercializing the R&D that takes place in our labs can generate significant economic opportunities. I will share just one example.

Descartes Labs is a New Mexico startup that uses artificial intelligence technology developed at Los Alamos National Laboratory to provide analysis and predictions based on satellite images of the earth. Early applications are in delivering crop-yield forecasts and analyzing trends in energy, construction, and the environment.

Today the company has its headquarters in Santa Fe and has raised close to $40 million in venture money, employs 70 people, and is a recognized leader in analyzing satellite imagery.

We need to help more research turn into innovative startups. Access to capital is key for entrepreneurs. Too many promising young companies fall to the valley of death, or get absorbed by behemoths where their innovation stalls because they cannot find the financing they need.

This is especially tough for innovators in rural and smaller cities. Good ideas and innovations occur everywhere, but more than three-quarters of venture capital goes to companies in San Francisco, Los Angeles, New York, and Boston.

Expanding access to capital can help us tap into the next generation of innovators creating new startups and new opportunities.

Lastly, immigrants are a key source of innovation and entrepreneurship. We cannot jeopardize these enormous contributions through short-sighted immigration policies, or by kicking out talented young people.

I am an engineer by training. I could talk about innovation and R&D and tech transfer all day long, but I look forward to hearing from our witnesses next and hopefully learning some new things along the way.

[The prepared statement of Senator Heinrich appears in the Submissions for the Record on page 31.]

Chairman Paulsen. Thank you, Senator Heinrich.

I will introduce our four witnesses, and then we will hear from each one of them individually.

First, Dr. Harold Furchtgott-Roth is a Senior Fellow and the founder and Director of the Center for the Economics of the internet at the Hudson Institute. He is the President of Furchtgott-Roth Economic Enterprises, which he founded in 2003. He is an Adjunct Professor of Law at Brooklyn Law School. From 1997 through 2001, Dr. Furchtgott-Roth served as a Commissioner of the Federal Communications Commission. Prior to his appointment to the FCC, Dr. Furchtgott-Roth served as Chief Economist of the U.S. House of Representatives' Committee on Commerce, where he was one of the principal staff involved in drafting the Telecommunications Act of 1996. Dr. Furchtgott-Roth holds an S.B. in Economics from the Massachusetts Institute of Technology, and a Ph.D. in Economics from Stanford University.

Dr. Michael Strain, who is with us today, is the John G. Searle Scholar and Director of Economic Policy Studies at the American Enterprise Institute. He oversees the Institute's work in economic policy, financial markets, poverty studies, technology policy, energy economics, health care policy, and related areas. His research has been published in peer-reviewed academic and policy journals. And before joining AEI, Dr. Strain worked at the U.S. Census Bureau's Center for Economic Studies, and the Federal Research Bank of New York's Macro Economic Research Group. Dr. Strain holds a Ph.D. in Economics from Cornell University. He was a graduate of Marquette University and holds an M.A. from New York University.

Also with us is Mr. Mark Mills, who is a Senior Fellow at the Manhattan Institute; CEO of the Digital Power Group; faculty Fellow at Northwestern's McCormick School of Engineering and Applied Science; and an Advisory Board Member of Notre Dame University's Riley Center for Science, Technology, and Values. Previously he co-founded and was Chief Tech Strategist of Digital Power Capital. Early in his career, Mills was an experimental physicist and development engineer at Bell Northern Research, Canada's Bell Lab. And he earned several patents for his work. Mills is also a published author and has contributed to The Wall Street Journal, The New York Times, and Forbes.com. He holds a degree in Physics from Queens University in Ontario, Canada.

Also with us is Dr. Darrell West, who is the Vice President and Director of Governance Studies, and holds the Douglas Dillon Chair at the Brookings Institution since 2013. He is the Founding Director of the Center for Technology, Innovation at Brookings, and Editor-in-Chief of Tech Tank. Prior to coming to Brookings, West was the John Hayson White Professor of Political Science and Public Policy, and Director of the Todman Center for Public Policy at Brown University. West is the author or co-author of 23 books, and has published more than three dozen scholarly articles in a wide range of academic journals. He holds an M.A. and Ph.D. in Political Science from Indiana University, and an A.B. in Political Science from Miami University of Ohio.

So we have a stellar group of witnesses that are here to share their thoughts and expertise with us today. And with that, we will begin with you, Dr. Furchtgott-Roth. Thank you for being here, for your opening statement, and I will recognize you for five minutes.

STATEMENT OF DR. HAROLD FURCHTGOTT-ROTH, DIRECTOR, CENTER FOR ECONOMICS OF THE INTERNET; FORMER FCC COMMISSIONER; HUDSON INSTITUTE, WASHINGTON, DC

Dr. Furchtgott-Roth. Thank you, Mr. Chairman, and thank you, Members of this Committee. It is an extraordinary honor for me to testify before you today about economic growth and innovation in America.

These are very important topics, and I am going to focus on the information sector, which is the sector I follow most closely.

I have prepared testimony, which I hope will be entered into the record. I am not going to read it all. In fact, I am going to provide separate comments.

My own research shows that a disproportionate share of American economic growth in the past generation is attributable to the information sector. I have three simple messages to share with you today:

Global economic growth in the past generation has been more profound than any in prior history, and innovation in the information sector was at the core of that growth.

The United States played a pivotal role in innovation in the information sector. Important factors included increased protection of property rights, a lighter regulatory approach, and an emphasis on competition.

And third, despite early receptivity to the internet, governments in other countries today are threatening the further development of the information sector.

The five largest corporations in America today by market capitalization are all in the information sector. Amazon, Apple, Google, Facebook, and Microsoft. They are also among the largest corporations in the world.

These are all innovative companies, and together with smaller companies in the information sector all have contributed to innovation and economic growth in America. Countless private companies and startups compete in this sector. Ask a 20-something in America or anywhere around the world where they would like to work, and chances are they're going to say: In a company in the information sector.

These new companies have provided the world with new technologies, and have captured the imagination of the next generation. Why did these companies develop in the past generation and not before? And why did they develop in the United States and not so much elsewhere?

Some might point to extraordinary entrepreneurs and technologists such as Bill Gates, Jeff Bezos, Steve Jobs, Sergei Wren, Larry Paige, and Mark Zuckerberg. Others might emphasize critical technologies developed in past generations that enabled the further development of the information sector.

No doubt these and other factors are important, but great entrepreneurs are born in every generation, in every country. What made the information sector in the United States over the past generation different?

Consider that much of the sector was founded in America. The information sector benefited from three conditions that changed in America over the past generation.

In America we established clear property rights in the information sector. We had a determined lighter regulatory approach. And we also, by statute, mandated more competition.

Each of these factors was important to the development of the information sector in America over the past generation. Congress changed laws, and Federal agencies adopted rules that enabled more innovation and economic growth in the information sector. The rest is history.

I have also been asked to address why productivity has slowed in recent years. I was asked the same question 40 years ago when I arrived at Stanford University. It became the topic of my dissertation.

The answer today is, sadly, much the same as it was four years ago. We know only part, but not all of the reasons. It is much the same across all industrialized countries.

One of my professors at Stanford, Moses Abramovitz, once described total factor productivity as a measure of our ignorance. It still is.

Having said that, let me briefly note a few major reasons for recent productivity slowdowns:

One, increased share of the economy in the service sector. Output is measured largely as revenue in the service sector, and it is very difficult to measure total factor productivity in those sectors.

Second is increased obsolescence of products indicates rapid quality improvements that are not easy to measure. Take a look at your Smart Phone. There is no market today for an iPhone Version One. It is obsolete. But you can look at a car manufactured in 2009 and there is a good market for it, as there is for a ton of steel. What we have is rapidly improving quality of products that are very, very difficult to measure.

Nonetheless, there has been a pronounced decline in total factor productivity in recent years, even in sectors that historically have shown rapid increases in total factor productivity, such as manufacturing, agriculture, mining, and utilities.

So as Professor Abramovitz once said, total factor productivity remains a measure of our ignorance. There are a lot of explanations, but we don't have them all yet.

Thank you, very much.

[The prepared statement of Dr. Furchtgott-Roth appears in the Submissions for the Record on page 33.]

Chairman Paulsen. Thank you, Doctor. And our next witness we will hear from is Dr. Strain. Thank you for your opening statement. You are recognized for five minutes.

STATEMENT OF DR. MICHAEL STRAIN, DIRECTOR, ECONOMIC POLICY STUDIES; JOHN G. SEARLE SCHOLAR, AMERICAN ENTERPRISE INSTITUTE, WASHINGTON, DC

Dr. Strain. Well thank you, Mr. Chairman, and Members of the Committee. It is an honor to be here.

How can Congress foster innovation? What are important ways to improve the skills of workers, helping to enable individuals to innovate? Education reforms designed to teach 21st Century skills is critical.

A stronger emphasis on work-based learning for workers is critical. And in my view increasing the number of highly skilled immigrants is also critical. Many of the most innovative companies in the United States were founded by immigrants.

Government has a role to play in supporting the basic research that innovation requires. Two important ways government supports innovation are through funding basic research, and through producing economic and social statistics required by businesses, researchers, and policymakers.

Beyond encouraging innovation through increasing skills and supporting basic research, there is a wide variety of action government can take. Avoiding excessively high tax rates, reducing regulation and other barriers to technological progress, and maintaining a posture of openness to the rest of the world through international trade are just some of the ways public policy can support innovation. Congress can also foster innovation by helping to create and enforce an appropriate regulatory environment. Likewise, imprudent regulation can stifle innovation, slowing economic growth and the rate of improvement of living standards.

I have been quite concerned about imprudent regulation recently in the conversation around big tech. It is common to hear calls from both the political left and right to "break up" major technology firms using the government's antitrust powers.

In my view, such action would be a major policy mistake. For the past half-century the Federal Government has followed the best standard that experts have crafted to identify anticompetitive behavior: consumer welfare. More specifically, when asking whether a firm is hurting competition, the following question should be asked:

Is the company reducing the welfare of consumers by pushing up prices that consumers face, and/or by reducing the quality and variety of products and services that consumers enjoy?

This antitrust standard stands in contrast to a different view which rests on the presumption that large and powerful companies should be suspect simply because of their size, under the assumption that with size comes undue economic power and the lack of competition. I would highlight three reasons why the latter view is inferior to the consumer welfare standard.

First, it is much more vague and harder to define. This vagueness invites regulatory mischief at worst. More than that, though, is the concern that due to its vagueness regulators might be swayed more by the public debate around a particular company than by relatively more objective metrics.

Second, the view that is suspicious of size ignores the good things that come from size. Economies of scale allow companies to produce goods and services more efficiently and at a lower cost than relatively smaller firms. These efficiencies can take many forms, including more specialized management and production techniques.

Third, focusing on size distracts regulatory attention from consumers. This argument is equivalent to asserting that consumer welfare should be the regulatory goal in a normative sense.

Big tech has significantly increased consumer welfare. Consider prices. Many products are offered to consumers free of charge. Amazon does not sell its products at a price of zero, but it has sig-

nificantly reduced the prices faced by consumers for many products to the point that some argue that Amazon may be lowering the rate of consumer price inflation for the overall economy.

Now consider product quality and innovation. The services mentioned above are all remarkably innovative. In addition to them, for example, Apple first put an entire music library into the palm of our hands, and then put a computer in all of our pockets. Major technology companies spend significant sums of money on research and development for new products in order to foster innovation.

Alphabet, the parent company of Google, spends 16 percent of revenue on research and development. Facebook spends 21 percent. Microsoft spends 14 percent. These ratios are far higher than for other companies. For example, General Motors, General Electric, Proctor & Gamble, and AT&T each spend less than 5 percent of revenue on R&D.

In addition, there is more churn in the technology industry than many may seem to think. It was not long ago that the dominant web browser was Netscape, not Google; that the dominant email service was not gmail; and that America Online was the dominant ISP.

It is imprudent to assume that Google, Facebook, Apple, Amazon, and other tech giants of today will be dominant in perpetuity. The public conversation also seems to misrepresent the actual dominance of these companies in the present day. For example, despite concern about Amazon's dominance, it is the case that online sales represent less than 10 percent of total retail sales. Walmart's revenue is more than twice that of Amazon's.

In summary, I do not view big tech as a threat to consumer welfare or innovation, and I am not convinced by arguments that antitrust action is required to advance these goals. Instead, big tech is advancing consumer welfare through offering consumers a wide variety of high-quality products at low and sometimes zero prices.

It is also advancing consumer welfare and innovation in the future through high amounts of spending on research and development which will fuel tomorrow's innovation. And that innovation will in turn fuel faster economic growth and higher living standards for American families. Thank you.

[The prepared statement of Dr. Strain appears in the Submissions for the Record on page 46.]

Chairman Paulsen. Thank you, Dr. Strain. And now we will welcome Mr. Mills for your opening statement. You are recognized for five minutes.

STATEMENT OF MR. MARK P. MILLS, SENIOR FELLOW, MANHATTAN INSTITUTE FACULTY FELLOW, McCORMICK SCHOOL OF ENGINEERING, NORTHWESTERN UNIVERSITY, WASHINGTON, DC

Mr. Mills. Thank you, Chairman Paulsen, and Members of the Committee.

As this Committee knows, when it comes to understanding "How the Innovation Economy Leads to Growth," one is necessarily engaged in forecasting technology. And with all due respect, the track record on technology forecasting for Congress, and most pundits

and especially economists, again with all due respect to my economist colleagues, is dismal at best.

Forecasting can be a dubious science, but it is serious business. My favorite aphorism in this regard dates back to 1963 when physicist and Nobelist Dennis Gabor wrote, "The future cannot be predicted, but it can be invented."

Despite recent innovations, there is today a popular forecasting thesis that essentially says we live in a time of a new normal where foundational innovation has run its course. The "New Normalists" don't propose that there is an end to the kind of technology disruptions we are witnessing now with social media and the internet's impact on politics and culture, instead they claim innovation is now a kind of froth on top of a paradigm of permanently slower economic growth because nothing really fundamental is happening in innovation.

The New Normalists misinterpret, though, the record of recent slow growth we have been living through, in fact an interregnum between great technological cycles. History offers a lot of examples of this phenomenon, but permit me to illustrate just one recent example of energy domains where technology forecasting offers specific lessons also relevant for manufacturing and health care.

When the Department of Energy was created 41 years ago, nearly every forecaster said, to use economic terms, hydrocarbon technology productivity had stalled out. It would not be able to affordably supply energy at the scale society would need in the future.

Policymaking then effectively focused on a kind of palliative care for hydrocarbons: banning exports, constraining consumption, creating strategic reserves. And over the decades a cumulative $500 billion was spent by the Federal Government in the pursuit of technologies that were forecast to be essential to replace hydrocarbons.

We now know what happened. Engineers and the private sector invented a new technology that unlocked America's vast shale fields that turned out to be astonishingly productive. Shale tech has added 2,000 percent more energy to the United States over the past decade alone than have solar and wind combined.

But those on the front lines of the shale revolution, and the few forecasters who did anticipate what would actually happen, were at that time generally ignored or either viewed as engaged in "old think" or in the pockets of entrenched industries.

As some on this Committee know, my written record shows that I was counted amongst those in the history's minority. There are a couple of lessons from energy's history that are relevant:

Noisy public debate and aspirational forecasts can hide the real underlying trends. And what appears to be innovation stalling out is often a pause, the interregnum, between eras as engineers and industries perfect and adopt new technologies.

The question today is what signals are we missing hidden in the media noise about the demise of manufacturing, the claimed inevitability of cripplingly higher health care costs?

In my submitted testimony for the record I have addressed both of those, but in my brief oral remarks I will highlight health care.

There is a lot of excitement these days about information systems applied to health care, the rising power of algorithms and ma-

chine learning. In fact, we are likely seeing a new battle for health care efficiency launched by the announced collaboration between Amazon, Berkshire Hathaway, and J.P. Morgan.

And information systems will add valuable efficiency to administering existing health care services and the management of records and insurance. But doing better with existing data and therapeutics isn't enough for a real revolution in health care productivity.

Information systems inherently depend on acquiring more and better information. One has to have a physical means to act on that information, as well. Fortunately we're on the cusp of a technological revolution in biological data acquisition and diagnostics and therapeutics. A lot of attention has been afforded to the promise of genetic engineering, which itself is, information centric, but the other two domains are equally critical: diagnostic tools, and information acquisition.

There is now a clear path to commercial bioelectronics that are body-compatible, implantable, even digestable. Bioelectronics will ultimately rival in scale the traditional silicon electronics industry and create a tsunami of heretofore unavailable health-centric data.

Much of that data will end up being channeled through radically new kinds of diagnostic tools, many soon in the hands of consumers not just professionals. There are far-reaching implications with the prospect of nearly every citizen possessing a useful diagnostic device.

Apple, for example, is well aware of the fact that features inherent in or that can be added to an iPhone constitute an implicit if not explicit classification as a medical device.

Last year's X Prize, awarded for a portable diagnostic tool, was a dramatic example of the kinds of devices that were once just the stuff of science fiction. That prize was awarded for inventing the Star Trek Tricorder.

For those who are not science fiction cognoscenti, the space ship's doctor would wave a hand-held tricorder over a patient to obtain an immediate diagnosis. The real-world X Prize was for a mobile device that was able to diagnose 13 health conditions and continuously monitor 3 vital health signs. All this says nothing about the revolutionary health care technologies emerging from a class of practical robots and so-called co-bots, the latter working collaboratively with people. These will unlock not only more hyper-precise and minimally invasive surgery, but also radically more productive tools for elder care and rehabilitation.

For the record, the same trifecta of technologies—computing, new materials, and new machines—is signaling a manufacturing productivity revolution as well.

History shows that economy-moving revolutions in technology have never been predicted by economists. Instead, they've been invented and propelled, usually unexpectedly, by innovators. If there is a central for policymaking, it's that instead of directing innovation, it is critical to ensure that there's an environment that doesn't impede innovators. Thank you.

[The prepared statement of Mr. Mills appears in the Submissions for the Record on page 53.]

Chairman Paulsen. Thank you, Mr. Mills. And now we will hear from Dr. West. You are recognized for five minutes, thank you.

STATEMENT OF DR. DARRELL M. WEST, VICE PRESIDENT AND DIRECTOR–GOVERNANCE STUDIES; FOUNDING DIRECTOR, CENTER FOR TECHNOLOGY INNOVATION, BROOKINGS INSTITUTION, WASHINGTON, DC

Dr. West. Chairman Paulsen, Ranking Member Heinrich, and Members of the Joint Economic Committee, so thank you for the opportunity to testify at this hearing.

So today I want to summarize my thinking on "The Innovation Economy." My latest book is entitled "The Future of Work: Robots, AI, and Automation," and it looks at the impact of new technologies on the workforce, education, and public policy.

I also have a new paper, co-authored with Brookings President John Allen, on how artificial intelligence is transforming the world.

Based on this research, it is clear that the Federal Government plays a vital role in encouraging innovation. I think there are several steps that would increase our economic growth and make sure the United States does not fall behind other leading nations.

First I argue we need to increase Federal R&D. Right now the U.S. spends about $495 billion on R&D, with 72 percent of that money coming from the business sector, and only 11 percent coming from the Federal Government.

If you go back to the 1960s, the Federal Government provided 65 percent of R&D, and we saw NASA land a man on the Moon. In 1969 we planted the seeds for today's internet through a Department of Defense communications tool called ARPANET. So we need to remember that historically the Federal Government has played a vital role in these advances, and we have done very well on innovation.

I think there is a danger of relying too much on the private sector for three-quarters of R&D because of its vulnerability to macro economic cycles. When the economy weakens, companies often slash their R&D and important strategic priorities can be lost through the decisions of individual firms.

Secondly, we need to maintain our international competitiveness. The United States now devotes about 2.74 percent of GDP to research and development. This is less than the 4.23 percent devoted by South Korea, 3.29 percent in Japan, and 2.93 percent in Germany.

Now China only devotes about 2 percent, but it has been increasing its R&D spending by anywhere from 14 to 20 percent every year since 2000. In fact, China accounts for 31 percent of the world's R&D increase during this 15-year time period.

Third, we need to address our critical needs in AI and data analytics. The U.S. Government is spending only about $1.1 billion a year on nonclassified AI. And just to contrast this, at it's 19th Party Congress, China announced it was going to spend $150 billion on AI and plans to become the global leader by 2030.

As John Allen and I argue in our recent paper, AI is the transformative technology of our era, and it is going to dictate our lead-

ership in terms of national security, economic development, and resource management, including many other areas.

Fourth, we need to promote STEM education. There are too few Americans studying science, technology, engineering, and math. Only 17 percent of Americans earn a STEM Bachelor's Degree, of those who are graduating from college, and 65 percent of them are male. This is far less than other nations. For example, in Korea 38 percent are graduating with STEM degrees. China is producing 4.7 million STEM graduates every year, compared to about a half a million in the United States. So we need to hire more science and math teachers in K–12. We need to pay those teachers higher salaries.

Fifth, we need to invest in our physical and digital infrastructure. We still have many Americans who lack access to the internet. We are moving to 5G networks. They are going to be faster, smarter, and more efficient, but they are going to require the deployment of small cell towers. We need to streamline the local approvals for those towers.

Six, we need to improve data access. Data analytics has tremendous potential to transform the public and private sector decision making. It will give us new insights into health care, energy efficiency, and national security.

The last point I want to make is just the need to improve our digital access. It is crucial that everyone shares in the benefits of our innovation economy. We currently have disparities by income, race, and education. There are major gaps for rural Americans, which I can appreciate having grown up on a dairy farm in rural Ohio. One-third of rural dwellers lack access to high-speed internet. So this limits their ability to participate in the innovation economy. So it is vital that we close that digital divide.

Thank you, very much.

[The prepared statement of Dr. West appears in the Submissions for the Record on page 61.]

Chairman Paulsen. Thank you, Dr. West.

And now we will have an opportunity to ask questions and have an answer period. I would ask Members, and remind them to keep your question period to five minutes. I will begin.

Dr. Furchtgott-Roth, the importance of technological progress and driving economic growth is widely agreed upon by members on both sides of the aisle. However, there is some disagreement about how much growth is actually left to be had, and how to encourage the necessary innovation that fuels technological progress.

Do you think there will be much stronger growth moving forward? And if so, why?

Dr. Furchtgott-Roth. Thank you, Mr. Chairman, for that question. I don't remember the author of this statement, but approximately 120 years ago someone famous said that we had reached the end of science, and all discoveries that were important had been made, and there really wasn't much point in pursuing it any further.

I think that any suggestion that innovation has reached an end, any suggestion that we are at the end, that technology is naive and misguided, I think there is an awful lot still going on.

Chairman Paulsen. Okay, and Dr. Strain, maybe you can provide some thoughts there. Dr. West had just mentioned how AI is sort of the transformational initiative that we'll be looking at in the future here. And sometimes we have a little bit of disagreement in terms of sort of how much resources that the Federal Government should not do in just basic research versus really encouraging more government spending, especially on R&D and other programs, to help investment in innovation and fuel growth. What is the reasonable approach? You know, sort of the basic foundations of research versus, you know, a lot more government spending in research and development? And how do you draw those distinctions and those lines?

Dr. Strain. Yeah, thank you, Mr. Chairman. I think it's an excellent question. I think there's a clear role, in my view, for the Federal Government to provide resources to universities and to scientists and to centers that fuel innovation. For some kind of clear economic reasons, those types of innovative activities generate public goods. Those public goods would be under-provided if it were left to the private market. And so there is a clear economic rationale for Federal funding there.

I think it is important that those resources be well targeted, because it is taxpayer money after all, and making sure that laws are written, and that agencies like the National Science Foundation are distributing money in such a way that the projects are selected carefully to encourage economic growth and to fuel innovation I think is very important.

I also think it is important that Congress ensure that the basic economic and social statistics infrastructure remain strong. That is important for policy making. It's important for private business activity, both of which have downstream effects on innovation and on economic growth as well. The immediate issue is the 2020 Census. That is far afield from this hearing, but it is something that is on my mind when your question was asked.

Chairman Paulsen. So you are sort of referring also to the fact that modern technology isn't often fully captured in existing measures right now with GDP and different productivity measures? Is there a way to—you know, what are your thoughts on sort of capturing those statistics or data to make sure we're making smart policy decisions?

Dr. Strain. Well I think it is an extremely difficult challenge, for the reason that my colleague mentioned. It is hard to kind of compare the price of an iPhone 1 in the year 2018 to an iPhone 1 in the year 2009.

The people who work on these issues over at the Bureau of Labor Statistics, and throughout the Federal statistical system, are very capable people who are doing a good job with what they have. And I think making that sort of measurement issue a priority for them would be a way to move the ball forward there.

Chairman Paulsen. And, Mr. Mills, just in my final minute, but, you know, you mentioned the future can't be predicted but it can be invented. Do you have some other thoughts?

Mr. Mills. Well, I do. In fact, one of the themes that we are hearing is this challenge of thinking about what is the role of gov-

ernment. And I am extremely enthusiastic about the proposition that government should spend more money on basic research.

However, I think we have a definitional problem between what are basic research and science order projects. So putting a man on the Moon is engineering. It's not basic research. It's not science. We do learn science along the way, but it's an engineering project.

I worked as both an engineer and a scientist. I admire both domains. Often never the twain shall meet. And I would like them not to meet so much in the government domains. Other than for Apollo programs and aircraft carriers, I think the government should focus on basic science.

If you look at the history of the sort of disquisitions that come from Nobel Laureates, what you will find as the common thread on there in their awards is that they had done research that was driven by curiosity. In fact, they use those words. That these great discoveries that advance humanity didn't come from directed research, but they were allowed to do research that was driven by curiosity. A tough thing to fund, I understand, but I think it is where the government has a critical role.

Chairman Paulsen. Thank you. Alright, Ranking Member Heinrich, you are recognized for five minutes.

Senator Heinrich. Thank you, Chairman.

I will start with a comment, Mr. Mills, because I think that they should actually meet more. You look at a national laboratory like Sandia, and one of the keys to their success is the cross-pollination that occurs there between basic science and engineering. And that actually played a key role in the development of the hydraulic fracturing that you referenced in your testimony.

I think it is that cross-pollination that we oftentimes fund things in silos and don't have the full benefit of their leverage.

Dr. Strain, I want to jump to you because you talked a lot about some of the big information sectors. You talked about Amazon in particular. I don't hear a lot about Amazon's low prices from my constituents—and that is not a critique of Amazon—but I do hear a lot about them on its impact to small main street businesses in rural areas.

And the point of raising that is that the benefits of innovation, especially on a gross level, a GDP level, are pretty easy to quantify. But they also have very real negative impacts to specific populations. And those benefits are not flowing equally or homogeneously across our country.

So how do we make sure, while supporting innovation, that innovation's benefits don't just accrue to urban and coastal communities?

Dr. Strain. Well thank you, Senator, for the question. It is a very important one, for sure.

I think it is the case that most people who live even in rural communities, even in communities where kind of local mom and pop stores are threatened by Amazon still benefit from innovation, and still benefit from technology companies, and benefit specifically from Amazon. The reason that those mom and pop stores are threatened is because Amazon is charging lower prices than the mom and pop stores can, and that people in those communities are

not going to the mom and pop store anymore because they are purchasing their goods elsewhere.

Senator Heinrich. But most of them, my point is, would not choose, you know, a quarter or a dollar off their box of soap that gets delivered to their house if they have to trade that for their neighbor down the street no longer being able to keep a retail shop open.

How do we get the benefits of that innovation into those communities so that there's a vested reason for them to want to be part of the innovation economy?

Dr. Strain. It is a classic example of somewhat diffused benefits and concentrated costs. So there are some people who are really bearing the brunt of this sort of change, and then many, many people who are benefiting from it. But the people who are bearing the brunt of it, that weighs heavier on them and there are a fewer number of them.

It is a classic example of the kind of creative destruction that's the hallmark of a market economy. I think the wrong solution is to try and stop innovation, and the wrong solution is to try and tax companies——

Senator Heinrich. So let's get to the right solution. I'm running out of time.

Dr. Strain. The right solution is harder. I think what we need is to have kind of a robust set of policies designed to create on-ramps to opportunity for people who are negatively impacted by technology. And that's why I mentioned in my testimony things like work-based learning, and similar programs.

Senator Heinrich. Dr. West, do you have a thought on this?

Dr. West. The right way to maintain innovation that we all value is to keep the startup economy that has been crucial to the tech sector and the greatness of America. And here I have one major concern.

We have been compiling data for 40 years on the number of startups in America. In the last decade there's been a dramatic drop in the number of startups. If you look at the period from 1970 to the mid-2000s, America averaged between 500,000 and 600,000 startups. Now we are down to 450,000. So keeping that emphasis on competition and helping small businesses start off is absolutely crucial.

Senator Heinrich. Let me ask you about something that specifically impacts small businesses. Yesterday I met with recently departed FCC Commissioner Mignon Clyburn, and she emphasized ensuring that all Americans have access to a free and open internet, and how important that is to foster innovation in places where it is particularly hard.

What about the digital divide? You've talked about that. And what about a free internet? Does net neutrality promote or stifle innovation, Dr. West.

Dr. West. In terms of the digital divide, as I believe you pointed out in your opening statement, there are 19 million Americans in rural areas that do not have access to broadband. One-third of people who live in rural areas lack access to high-speed broadband.

If you want to apply for a job today, many companies, and Brookings has done the same thing, have converted to online applica-

tions. You have to have access to the digital economy in order to get a job.

In terms of the open internet, it is important to maintain the open internet. One of the reasons why our country has done so well in innovation over the last couple of decades has been that we treat all internet traffic the same. There's been no discrimination in the traffic. You can't slow down anyone's traffic.

If you're the small guy operating a small convenience store on the corner, your traffic gets treated the same as the large company. So it is important to maintain that.

Chairman Paulsen. Thank you. Now we will listen to the Vice Chairman of the Committee. Senator Lee, you are recognized for five minutes.

Vice Chairman Lee. Thank you, Mr. Chairman. Thanks to each of you for coming. Your expertise brings a lot to our Committee.

The FAA has banned commercial flight of supersonic aircraft in this country. This ban was found in a regulation that was promulgated back in 1973, so some 45 years ago. Today, in 2018, commercial aircraft travel no faster than they did 50 years ago, in part as a result of this.

And significantly, the Concord, the heavy, clunky supersonic commercial aircraft that was in use at the time the regulation was promulgated, has been grounded today in part as a result of those regulations.

But when we look at this today, we realize that there are some companies that have developed technologies using stronger, lighter materials that could achieve a greater degree of fuel efficiency, and perhaps most importantly there are some companies that have developed technologies that they claim can result in commercial grade supersonic travel that is 30 times quieter than the Concord was.

And this seems like an example of the problem we face when regulations do not keep pace with current technology. And so, Dr. West, I would like to ask you a question about this.

What do you think some of the benefits to the United States might be from supersonic travel? And is this something that you think we ought to continue to stick to? Is it time for Congress to revisit this idea of banning overland supersonic commercial travel?

Dr. West. I think there has been so much innovation over the last 40 years that any regulation from 40 years ago deserves another look. Because I remember when the Concord was flying, there was concern at the time about sonic booms that were annoying people on the ground, and so that was one of the reasons that created a complication there.

But I would not be surprised if manufacturers have figured out ways to handle that; that there are noise abatement procedures that would make a difference. So we certainly need to constantly take a look at regulations.

We need to move into what I would call smart regulation, which basically is well designed and focuses on specific problems.

Vice Chairman Lee. And just because I find this area interesting, I would note in response to your observation, it is my understanding that the sonic boom is somewhat analogous to the wake that travels behind a boat or a ship. And just as the size and

the shape and the materials used in a boat or a ship can affect the type of wake it casts, there are ways of diminishing the impact of the sonic boom. And that is yet another reason why we ought to revisit this nearly half-century-old regulation. It is really out of date.

In the coming years we are going to see the deployment of 5G technology; 5G wireless networks are going to revolutionize all sorts of things. But they require the deployment of a large number of small antenna systems, somewhat different from our current cell phone networks.

The dawn of the 5G era brings a whole lot of opportunities in the way we will travel, and the offering of things like telemedicine, in the travel of autonomous vehicles both on the land and in the air in drone use, and a greater connectivity generally.

Dr. Furchtgott-Roth, I would like to ask you. These benefits can be impeded by government regulations that could stop the deployment of this technology. Is our current regulatory framework prepared to handle these challenges, the challenges associated with the deployment of a 5G network?

Dr. Furchtgott-Roth. Senator, that is a very good question. A lot of people are very concerned about the deployment of 5G technologies, and in fact are concerned about whether regulation will get in the way.

I think at the Federal level, and I would say even at the State level, that most people in government are trying to take great efforts to be sure that there are not impediments to the deployment of the new technologies.

There are a handful of municipalities around the country that want to create new regulations on the siting of towers, or in the case of 5G networks it's not going to be towers, it's just going to be a tiny little box that can stick on the side of a building. And so I think there is some concern that municipalities may be impeding the deployment. We will have to see.

Vice Chairman Lee. Thank you. I see my time has expired, Mr. Chairman.

Chairman Paulsen. Thank you. Senator Peters, you are recognized for five minutes.

Senator Peters. Thank you, Mr. Chairman. Thank you to our witnesses today. I appreciate the conversation that's been very interesting.

I am concerned about the growth of innovation that we see in this economy. There are other sectors outside of IT and health care which of course are big drivers for the economy right now, but looking at it more broadly coming from Michigan, particularly with a lot of older industries there.

In a recent Economic Innovation Group study I was struck by a finding that they cite, another study, that shows that in the United States today only generates two nonhealth and non-IT patents for every one billion dollars in GDP. And so taking out IT, taking out health care, looking at a decline of dynamism generally in the rest of the economy, which is a very large part of our economy. And in the 1980s it was four. So basically it's half. The innovation outside of IT and health care, at least as measured by the number of pat-

ents, which is just one of many measures you could have, has dropped in half.

Dr. Furchtgott-Roth, any ideas? You've certainly talked in your testimony. We have a lot of explanations for what's happened to productivity. And you mentioned the iPhone example, but that would be out of this. This is innovation within these other industries.

Dr. Furchtgott-Roth. Thank you, Senator. That's a very important question. If I had my econometrics hat on, I would say there's an inflation issue. If you're comparing patents per dollar of activity in the 1980s with today, you're going to have a—it's not surprising to see some decline per dollar.

But I think the real question you're asking is really far more profound than that, which is: Outside of some sectors of the economy, probably particularly high-tech, health care, the United States no longer has the global position that it had a generation ago. And I think that is very troubling. It is something that I hope this Committee will be able to address, to figure out—I focus a lot on the information sector. That is an area where the United States has a very strong global position.

There are other industries where we have lost that edge. And I am very troubled about actions that are being taken by other governments that threaten the information sector, and no doubt other sectors of the economy.

Senator Peters. I appreciate that. We need to work more on this, because this is a fundamental question for us to deal with. And I think part of what folks have talked about, at least in my reading, and it's correlated I think to what Dr. West talked about, is the decline of new business formation. Because it's a lot of those smaller businesses in particularly these other industries where you can get more innovation as a result of that.

Dr. West, you have talked about the decline of that. One other statistics that I have been looking at, and would love to have your comments, and this doesn't refute but maybe is a little counter to what Dr. Strain said, but is that we have seen just a concentration in our economy with larger and larger firms across the sectors. In fact, I think one of the statistics are, if you look at over the last 20 years we have more concentration now in more industries than we have had in the past. And as you have bigger and bigger firms, it becomes more difficult for a small firm to start in those industries. Dr. Strain mentioned the advantages of size, which there are significant ones including economies of scale, et cetera. Do you believe—and where's the academic literature—that because of an increasing concentration across all industries that we've actually seen a decline in dynamism in the economy as a result of that, and the competitive advantages that big firms have?

Dr. West. I do worry about small businesses getting squeezed out of this environment. I think the competition is an issue, and we need to take a look at it. In 2014 in The Wall Street Journal, a Silicon Valley entrepreneur, Peter Thiel, wrote a famous column saying competition is for losers, and argued that monopolies are great.

I strongly disagree with that viewpoint. I think small businesses actually create a lot of the jobs. When we think back to the big tech

sector, you know most of those firms started in garages or dorm rooms. So it is really vital that we maintain an environment where small businesses can thrive.

Senator Peters. And in my remaining time—I only have 30 seconds and it's a big question for you—but you mentioned AI and the transformative nature of AI. It has also been argued, and I agree, that it is transformative, but it is large capitalized companies, big companies, that will be able to use AI more efficiently and more effectively than smaller companies, and could actually further concentration.

Is that a potential problem?

Dr. West. It's a potential problem, but the economic payoff of AI is just so substantial. Price-Waterhouse Coopers just put out a study in which they estimated AI can increase global GDP by over $15 trillion.

Unfortunately, half of that money is going to go to China just because they are investing, and they are really putting a lot of effort into there. Only about 20 percent of that is going to accrue to North America. So that is an area where we need to do better.

Senator Peters. Thank you.

Chairman Paulsen. Representative Handel, you are recognized for five minutes.

Representative Handel. Thank you very much, and thank you to each of the witnesses.

Mr. Mills, I saw you shaking your head a little bit about the comment that AI is going to primarily benefit larger companies. Would you like to tell me what you think about that?

Mr. Mills. Yeah, I don't think that's what's going to happen, but we're back in the forecasting game here. AI is in early days of deployment. In fact, the AI community is struggling with the same kind of reproducibility challenges that the medical community and the science community at large has in terms of claims.

But more interesting is that, what I think will happen is that AI is going to democratize the nature of computing and will actually help small businesses. So we're at an odd phase in the computing infrastructure of the world.

So you have the big guys competing to create these broad cloud infrastructures of access to cheap computing. There's fierce competition among a half-dozen major players, another half-dozen very significant players. There will be some winners, but I don't think the consolidation is going to happen very quickly.

And what they are doing is providing astoundingly cheap, essentially free, and for small businesses actually free supercomputing in the cloud running AI. So I am a partner in a boutique venture fund that invests—not on the coasts; we invest in the Heartland—in software. And one of our companies is an AI company that does AI primarily for the resource industries in oil and gas.

But they get—and they are proud of this AWS compute power for free, Amazon offers startup companies. It's a hook. They want them to stay in when they become bigger. But that hook is chasing a rapidly declining cost of AI. It means that the supply chain advantages Amazon had in the early days get democratized to the mom and pop shops.

I am, frankly, worried about regulating big tech, like Dr. Strain is, but I am particularly enthusiastic about the democratizing effect of what will become sort of an era of embodied computing universally.

Representative Handel. Well it is interesting. I, just coincidentally, had a meeting with a young fellow, literally a very young fellow, in his early 20s, who is an extraordinary innovator and inventor in the AI sector, and he has a very small company, and he has been able to monetize it, and he is doing extremely well as a 23-year-old.

So what he said to me—and this goes to my next question for you, Dr. Strain—he said that he sees AI and this breakthrough as, well, some would be concerned that it is going to take jobs away from Americans, he rather sees it as a way to help individuals do their jobs better.

And as we have seen technology advances come forward, we always hear the cry that, oh, it is going to be the demise of the worker and the workplace. But we really have not seen that come forward.

Do you have some thoughts, Dr. Strain, on that?

Dr. Strain. I do. It is such an important question. My answer will be somewhat similar to my answer to Senator Heinrich. This will be a situation where you have concentrated costs and diffuse benefits.

So there will be some people who are impacted quite negatively. But the technology will accrue overall to the benefit of everybody, and it will accrue to the benefit of the average American, if you will.

There have been many periods of history within the United States and in Europe where new technologies have kind of come to the fore, and there has been concern that those technologies would make human work obsolete. Those concerns have never come to pass.

In my view, we are not looking at a situation where those concerns will come to pass at any point in the near future, as well. New kinds of work will be created.

Representative Handel. Great. Thank you.

And in my remaining time, for Dr. Furchtgott-Roth, you made a comment that you, in your opinion the United States has lost its edge when it comes to innovation and discovery. Why do you think that? And what can we do from a policy—put the money investment part aside—but policy framework, can we do to help recapture, regain our place in the innovation hierarchy?

Dr. Furchtgott-Roth. Well as I mention in my comments, I think there are three elements. One is clear property rights. The second is a lighter regulatory touch. And the third is competition.

I think all three of these are important and necessary for innovation. And my comment was in response to Senator Peters about certain sectors of the economy where we used to be globally dominant and no longer are.

Representative Handel. Alright, thank you. And I am running out of time and I yield back.

Chairman Paulsen. Representative Adams, you are recognized for five minutes.

Representative Adams. Thank you, Mr. Chairman. And thank you for your testimony, gentlemen.

In 2017 the National Institutes of Health, the primary government agency for biomedical and public health research, spent $19 billion on research grants. These grants funded thousands of laboratories across the country. And since the majority of this work is done by academic researchers, these grants are an important source of Federal funds for universities and their surrounding communities.

In short, research funding translates into greater economic opportunity for the researchers, their schools, and the communities hosting them.

So perhaps you can imagine my concern at finding out that of the top 100 organizations that NIH gives research funding to, no HBCU, Historically Black College or University, is included. Not one was on the list.

So, Dr. West, what are the implications for HBCUs being left out of the bulk of NIH funding?

Dr. West. Well I would say it is devastating for them, and it is devastating for their local economies. Because we know, as you suggest, R&D really drives economic development. In fact, people have suggested the multiplier effect is 5 to 1, or 10 to 1. It is a huge economic effect.

In many local communities, economic development is based on Eds and Meds. It is the education sector and the biomedical sector and the hospital sector that drives a lot of economic growth.

So if the HBCUs are not getting the grants, it is really going to limit what they can do research-wise, but also have a devastating impact on their local communities.

Representative Adams. So what about the—what implications do you find of the funding disparity for the students that these universities teach?

Dr. West. It means that they will be denied opportunities, especially in the STEM fields, and in biomedical areas, and those are going to be the growth areas in the future. So if they are coming out of college and they do not have those skills, it is going to limit their opportunities.

We know that by 2044 America is going to become a majority minority country, and so it is crucial that we recruit more women into the STEM field, but also more minorities so that that sector represents the full diversity of America.

Representative Adams. Thank you. The topic today is "How Innovation Helps the Economy Grow." And I am really on HBCUs because, not only did I attend one and spent 40 years on the campus, I really know the impact that these colleges and universities have not only on our economy but also on our students.

So if HBCUs and other minority-serving institutions continue to be under-funded in regards to Federal research grants, can the economy grow equally?

Dr. West, that is a question for you.

Dr. West. Well the short answer is, no. And one of the concerns that I have is, if you look at the venture capital money today, three-quarters of it is basically concentrated on the coasts. So most of America is being left out of the growth areas of the economy.

Something like two-thirds of GDP is now taking place in less than one-third of America. Those geographic inequities are devastating. It makes most of the country feel left behind, while the coasts are running ahead and doing very well.

It is bad for our country, and it has a devastating effect on our politics.

Representative Adams. So can the African American community expect to see the same economic impact from government research grants if HBCUs are not receiving proportional Federal funding that the PWIs, or the Predominantly White Institutions, receive?

Dr. West. There deserves to be greater representation there both from a fairness standpoint, but also from an economic development standpoint. Many of those schools are located in places that are not doing that well economically, and so this is one way in which the Federal Government can play a constructive role of helping communities that have been left behind by technology innovation and making sure that they are able to compete in the years going forward.

Representative Adams. Well thank you for your responses. You know, when you look at across the country we have got 106 or more of these schools, and it would really I think be important not only to them, to the students that attend them, but also to our economy for us to take another look there.

Thank you, and I yield back, Mr. Chairman.

Chairman Paulsen. Thank you. Representative LaHood, you are recognized for five minutes.

Representative LaHood. Thank you, Mr. Chairman. I want to thank the witnesses for being here today, and for your valuable testimony.

I know we have touched a little bit on competition here today. And when I think of the tech, or the titan firms that are out there, obviously some of them have been under scrutiny for what some would deem as somewhat sophisticated or calculated, and arguably anticompetitive practices.

For instance, a number of these tech companies have combined their ability to collect data and build algorithms to determine which products or services are trending. And once they have achieved those results, these same companies then can alter their search engines to favor their own products and services over their competitors, and even simply buy out their competitors.

And you add these companies' significant network effects where value is added to the company simply because a consumer chooses to use only that company's products or services. These firms gain significant market power. And I think we have seen that in a lot of different instances.

I guess from a public policy standpoint, when we think about what government can or can't do, how do we ensure that startups, which are the major drivers of innovation, are still able to compete and be able to have a market to innovate as a whole. And I think I'll start with Dr. West.

Dr. West. Thank you. I agree with your emphasis on competition. I agree that there is a problem in terms of the decline of startups in America.

My colleague, Bill Galston and Clara Hendrickson wrote a paper on this topic, which I would recommend to everyone on the Committee. And what they suggest is the need to update our merger review guidelines for the digital economy.

Many of those guidelines date back 20 and 30 years and have not really been updated, even though our economy has undergone major changes. So we need to kind of look at how we think about those types of things.

Representative LaHood. Dr. Strain.

Dr. Strain. I certainly think this is an extremely important issue, and I agree with Dr. West that looking at some of the merger rules is a reasonable course of action.

I think it is important to recognize that there is more complexity here than there may seem. So on the one hand it is the case that tech giants are buying smaller tech firms and kind of folding them into their conglomerate. And it is reasonable to speculate that that may be reducing innovation and reducing competition in the economy.

The flip side might also be the case. It could be that the opportunity to be purchased by a major tech firm is actually something that is incentivizing people to innovate and to create new tech companies. Their goal could be to be purchased.

And so it is an area that I think merits further study and further examination, but it is not immediately clear to me that, because Facebook purchased Instagram there is less competition and innovation than there otherwise would be.

Representative LaHood. Along those same lines, as we look at the Federal Trade Commission and the role that they play, does the FTC have a modernized set of tests and evaluations to adequately determine if and when the tech company is stifling competition or innovation, or is anticompetitive? Do you feel that their standards and evaluations are currently up to par on that? Do you want to comment on it, Dr. Strain?

Dr. Strain. Yes. I feel that the standards are the right standards. The standards focus on the consumer and on the welfare of the consumer. The standards focus on the prices that consumers face, on the quality and variety of products that are offered to consumers, and on whether innovation is being fostered, and whether competition is being advanced.

There are other standards, and other countries place emphasis on different things, but that standard has been the standard in the United States for the past half-century, and it still seems to me to be the correct and appropriate standard.

Representative LaHood. Thanks. Mr. Mills, my ears perked up when you mentioned the Heartland. I represent a District in central Illinois, Peoria, Illinois, is my home town. And you talked about investment in the Heartland when it comes to not necessarily the East or the West Coast.

How do we look at smaller markets? And what is the attraction to investing in tech in medium-sized markets or the Heartland?

Mr. Mills. Well the short answer is, to be mildly cynical, is that the pricing of the deals is better. So you are not competing against large venture funds that add a zero to the valuation of a company you want to invest in.

So you can find just the smart young men and women, and older men and women—I would note the Kaufen Index shows that the number of startups started by people over 55 is the same as the number under 35 as a percentage of startups.

It is attractive because there is a lot going on. But it is not attractive if you do not like traveling. So venture funds tend to like to invest in their geographical orbit.

I would like to point out that one of the big problems, having been a practicing venture capitalist and began one, and having taken a company through an IPO as the founding chairman and CTO, that the biggest problem that we have in getting new companies to not be bought by an Amazon, or be bought by a GM, or whoever, is that we've damaged the IPO process.

The finance regulatory system makes it extraordinarily difficult and extraordinarily expensive, and this has been well analyzed by a lot of academics, but as a practitioner being run through that mill I can tell you it is a very difficult, very painful process.

I know what it is designed to do, to protect innocent victims buying stock in companies that are charlatans, but I think the pendulum has swung too far.

Representative LaHood. Thank you. Thank you, Mr. Chairman.

Chairman Paulsen. Thank you. Representative Maloney, you are recognized for five minutes.

Representative Maloney. Mr. Chairman, I would like to thank you and the Ranking Member for calling this incredibly important hearing, and all of our panelists. I believe this is certainly one issue that we can firmly all agree on, that innovation and entrepreneurial drive is one of the defining characteristics, if not the defining characteristic, of America's success. And certainly it has been essential to our economic success.

And I am disturbed by some of your statements that we are losing our competitive edge and our really innovative success in this area.

I just have noted economically in my own District and around the country that retail stores are closing. They are just closing in droves. You have empty stores. And I represent Manhattan. It is a business district, but stores, particularly retail stores, are all going out of business.

I read an article last week that 18 major retail companies are going out of business. And I resisted buying online, but now I do everything online because it is faster and I do not have time to go shopping. But there are no more toy stores, clothing stores, they are all going under. And that is just one example of how a large conglomerate, in this case Amazon, is taking over.

And it just is common sense that when these large conglomerates go in and dominate, they are going to stifle the creativity in those areas, and the competition in those areas.

But I want to ask Dr. Furchtgott-Roth, in your testimony you state the need for strong intellectual property laws, and I agree that our property laws have brought many people to invest in our country. They trust our laws. They invest in our country. But in the past the high tech industry has benefited greatly from the fact

that workers often move from one company to another, taking their skills with them.

It has been argued that this cross-cultural or hybridization has been a significant factor in promoting innovation. If you look at the automobile companies that all came up in Detroit. The Silicon Valley with all these high tech companies out there. And now we see a trend where some companies have tried to enforce nondisclosure agreements that restrict the movement of skilled workers, or take a broad interpretation of what knowledge is proprietary. They are being forced to sign non-compete, won't go to another firm, won't share information.

Yet if you look at the history of the country, it was this cross-ideas that people would get in an area and talk to each other, go to another firm, do a startup. But now with these non-competes and this, that, and the other, I just like to think what kind of impact do you think these agreements have? And are they damaging innovation?

I would like to ask you, and I would like to ask Dr. West, about the impact of these nondisclosure, non-compete, won't go to another firm, you can't go to another firm in the same industry, that these industry high tech firms and others are forcing their employees to sign.

I even went to visit a high tech firm. I was just visiting it. And I was going in and touring it, and I had to sign a nondisclosure, will-not-reveal anything I learn during the trip that I had to just look at it.

So what is this going to have—true story; I couldn't believe it—but anyway, to the panelists, if you would start, Doctor.

Dr. Furchtgott-Roth. Yes, thank you. It is a very important question.

I think a lot of the non-compete contracts are very fact-specific. And I'm sure there are some that are very problematic and may have discouraging effects on innovation, and others may very well be necessary for companies to be willing to invest in employees and be willing to share information with them.

So I would be very—I am not in a position to make a blanket statement about their effectiveness. Maybe some of the other panelists have a stronger view.

Representative Maloney. Dr. West, do you have a——

Dr. West. Yes, I do have stronger views on that, so thank you for the opportunity. I agree with you that many of the noncompete clauses are overly broad.

I grew up in an era where most employees were free agents, and you basically sold your talent to the highest bidder, or where you wanted to work. I think we have gotten away from that, and I think that damages our ability to innovate, it damages competition, and it is probably part of this drop in startups that we have been seeing over the last 40 years.

Representative Maloney. I have one minute left, but I am going to ask, I guess it was Dr. Strain, you said that all of these huge conglomerates were not hindering, if I heard you correctly, the competition, and it was really still a small part of the profit, or the organizations. But I've got to tell you, I don't remember an antitrust suit in my lifetime. And yet if you read the history of our

country, there was one antitrust suit after another trying to break up monopolies.

I guess we did have one when we reformed the telecommunications system in America and said AT&T could no longer dominate everything, that there would be competition. And I would argue that is what brought us all of the new internet and high tech firms, is when we deregulated that we had a burst of activity where a young, brilliant kid could start their own company.

But we are fixing it so that it is becoming harder to happen. So I just want to throw that out. I am concerned about the domination. And I read an article that one major company begins every meeting by saying "Dominate!" We must dominate America's commerce. We must dominate the world in this area.

And I don't see that dominating brought us the innovation, that brought us the success that we have as a country. And if we lose that success, I think we lose a fundamental element of what America is.

I am very concerned about it. Thank you for calling this hearing, Vice Chair and Chair. I think it is very important.

Chairman Paulsen. Thank you. And let me just thank all of our witnesses for taking the time to appear before the Committee today. I want to remind Members, should they wish to submit additional questions for the record, the hearing record will be open for five business days.

And with that, our Committee is adjourned.

[Whereupon, at 3:27 p.m., Wednesday, April 25, 2018, the hearing was adjourned.]

SUBMISSIONS FOR THE RECORD

Good afternoon, and welcome to today's hearing on "How the Innovation Economy Leads to Growth."

The U.S. economy is not only growing, but it's also doing so faster.

GDP growth is rising, job creation is strong, average wage growth is improving, and inflation remains low.

These long-awaited positive results stem from the decision to unleash America's most valuable economic asset: the American people.

Tax and regulatory relief are allowing American families and main street job creators more breathing room and to do more.

Contrary to those who believed we were stuck at low growth, many economists expect as much as 3 percent GDP growth in 2018 and similar strong growth in 2019.

To achieve this, Washington needs to stay out of the way so that individuals are free to figure out new ways to solve old problems.

Such innovation is vital to sustaining our restored economic growth.

America has been a laboratory for invention since its inception, and it is that spirit that has led to our strength.

A report by the McKinsey Global Institute in March 2017 finds that many advanced economies rely on productivity gains far more than increases in the labor supply to drive economic growth.

Folks in the private sector know this when they ask questions like: How can we serve more customers in one day? How can we complete more orders in less time? How can I produce a product with fewer passes of a machine?

Those questions are how innovation becomes the primary driver of productivity gains.

We know we are blessed to live in the United States for a variety of reasons, but among those blessings are our fellow Americans who have generated remarkable technologies to lift our standard of living, to expand our horizons, to support U.S. leadership in the world, and to grow our economy.

Not all economic systems are equally conducive to such path-breaking innovations.

Every technological advancement of major economic consequence since World War II has come from the United States. That is no accident.

As we will hear from our witnesses, strong property rights, the rule of law, light regulation, and competition are critical conditions for visionary entrepreneurs, risk takers, and investors to generate the technological success we have seen.

American inventors, main street job creators, and resourceful factory workers will continue to deliver amazing advances-but that's contingent on Washington staying out of the way.

A brilliant idea or discovery is only the start. It has to be put into concrete form and developed. From there it has to be commercialized and disseminated throughout the economy before it actually boosts economic growth.

These steps can take a long time depending on how they are taxed and regulated, or how antitrust law is applied.

The highway to innovation is littered with potholes, traffic jams, and overturned vehicles. You can see this up close in my home state of Minnesota where an excise tax threatens the innovative medical device industry and could drive it away to other countries.

While the Federal Government has temporarily suspended that tax, innovators still face great uncertainty about their future.

Even more obstacles lurk along the path of international trade. Last year, this Committee held a hearing on digital trade. The takeaway is that the United States leads in digital products and trade that rely on the internet.

Yet the freedom of the internet faces challenges abroad, and the United States must strive to protect it. To remain credible in this mission, the United States must generally promote and defend the long-held American principles of unencumbered international transactions and trade.

Every day has the potential for game-changing technological breakthroughs.

Blockchain is an example of a technology at an early stage of development. Its potential for very wide application throughout the economy could be stifled by over-regulation.

The United States has the opportunity to continue to champion its Age of Invention, but only if we keep the engines of innovation running. We must protect the

ability of our market economy to perform at its full potential at home and in global markets.

I look forward to the testimony from our distinguished panel of witnesses today for clarity and guidance on how innovation can drive economic growth and American prosperity.

PREPARED STATEMENT OF HON. MARTIN HEINRICH, RANKING MEMBER, JOINT ECONOMIC COMMITTEE

Thank you for calling today's hearing on promoting innovation and accelerating economic growth.

Innovation drives economic growth and boosts wages. We need more of it and we need innovation to be more broadly shared across regions.

Other countries are moving forward aggressively to promote innovation, to support advanced manufacturing, and to boost the productivity of their workers.

To lead in the 21st century economy, the United States must remain at the forefront of game-changing discoveries and create an ecosystem that supports innovation across the economy.

The Federal Government plays a key role in this—funding and conducting R&D, investing in the human capital of our people, and ensuring that we are making the necessary investments in STEM.

STEM education and R&D are two innovation anchors.

We need to ensure that students everywhere have access to STEM pathways, and that starts with making sure that schools have the resources they need to recruit, train, and retain talented science and math teachers.

We need to expand middle-skills pathways into emerging sectors, and make a college education accessible and affordable for all Americans, so that every student has the opportunity to benefit from tomorrow's innovations.

The Federal Government remains the largest funder of basic research—that research which adds to our fundamental stock of knowledge, yet often would not be conducted without public investment.

This is the research that can help us solve the problems we don't yet know we have.

Basic research has driven major leaps forward—including mapping of the human genome, vaccines, breakthroughs in cancer research, and energy storage technology and the creation of the internet, laser, MRI and GPS.

The knowledge gained through this research has significant spillover economic benefits—increasing productivity, creating jobs, and accelerating economic growth.

That's why it's encouraging that the recent Omnibus agreement made significant investments in R&D.

Investments in basic research increased by almost 10 percent over the previous year, its largest annual increase since the Recovery Act in 2009.

Promoting innovation also means extending already developed technologies, like broadband, to communities currently without access.

Today, years after high-speed internet was first made available, 19 million rural Americans still lack access. The private sector doesn't have the incentive to extend broadband to remote, hard-to-reach communities.

The Federal Government must step in and fill the gap.

We also need smart policies that can help emerging industries grow. Targeted tax credits, competitive grants, and prize competitions are all levers Congress can pull.

The multi-year extension of the wind production tax credit is a good example. It is driving investment in wind farms in New Mexico and across the country.

Earlier this month, I toured the future site of the $1.6 billion Sagamore Wind Project in eastern New Mexico, which will be the largest wind farm in our state's history and create up to 300 construction jobs and 30 full-time operations jobs.

Programs like Laboratory Directed Research and Development (LDRD) authorizing a portion of a lab's Federal funding for cutting-edge R&D are also vital.

At Los Alamos National Laboratory in New Mexico, LDRD researchers generally account for one-quarter of the lab's patents and peer-reviewed publications.

Efforts to help commercialize technology developed at our national labs and research universities help to take a good idea and get it into production and out into the marketplace.

In New Mexico, we've seen how commercializing the R&D that takes place in national labs can generate significant economic opportunities.

I'll share one example.

Descartes Labs is a New Mexico start up that uses artificial intelligence technology developed at Los Alamos National Laboratory to provide analysis and predictions based on satellite images of the earth.

Early applications are in delivering crop yield forecasts and analyzing trends in energy, construction and the environment.

Today, the company has its headquarters in Santa Fe, has raised close to $40 million in venture money, employs about 70 people, and is a recognized leader in analyzing satellite images.

We need to help more research turn into innovative startups.

Access to capital is key for entrepreneurs. Too many promising young companies fall to the Valley of Death, or get absorbed by behemoths where their innovations stall, because they cannot find the financing they need.

This is especially tough for innovators in rural areas and smaller cities. Good ideas and innovations occur everywhere. But more than three quarters of venture capital goes to companies in San Francisco, Los Angeles, New York and Boston.

Expanding access to capital can help us to tap into the next generation of innovators creating new startups and new opportunities.

Lastly, immigrants are a key source of innovation and entrepreneurship. We cannot jeopardize these enormous contributions through short-sighted immigration policies or by kicking out talented young people.

I'm an engineer by training. I could talk all day about innovation, R&D and tech transfer.

But, now I look forward to hearing from our witnesses.

Prepared testimony of

Harold Furchtgott-Roth
Senior Fellow and Founder of the Center for the Economics of the Internet
Hudson Institute
Washington, DC

Before the Joint Economic Committee

April 25, 2018

I. Introduction and Overview

Thank you for the honor of testifying about innovation and economic growth before your committee today. I will focus on the information sector, which includes the Internet and communications industries. I have three simple messages to share with you today:

a. Global economic growth in the past generation has been more profound than any in prior history, and innovation in the information sector was at the core of that growth.

b. The United States played a pivotal role in innovation in the information sector. Important factors included: increased protection of property rights; a lighter regulatory approach; and an emphasis on competition.

c. Despite early receptivity to the Internet, governments in other countries today are threatening the further development of the information sector.

II. Qualifications

I am the president of Furchtgott-Roth Economic Enterprises. I am also a Senior Fellow at the Hudson Institute, where I founded the Center for the Economics of the Internet, and an adjunct professor of law at Brooklyn Law School.

I was a commissioner of the Federal Communications Commission ("FCC") from November 1997 through May 2001. In that capacity, I participated in all decisions of the

Commission, and I delivered testimony before numerous congressional committees relating to the work of the FCC.

From 1995 to 1997, I was chief economist of the U.S. House of Representatives Committee on Commerce. One of my responsibilities was to serve as a principal staff member helping to draft the Telecommunications Act of 1996.

From June 2001 through March 2003, I was a visiting fellow at the American Enterprise Institute for Public Policy Research ("AEI") in Washington, DC. There I wrote a book, *A Tough Act to Follow?: The Telecommunications Act of 1996 and the Separation of Powers*.

From 1988 to 1995, I served as a senior economist at Economists Incorporated. I previously was a research analyst at the Center for Naval Analyses. I also served as a research analyst at the Congressional Budget Office, and my first job in Washington was as a summer intern at the Senate Appropriations Committee.

My academic research concerns a variety of topics related to economics and regulation. I am the author or coauthor of four books on cable television, telecommunications, and international trade, and I have published many scholarly and popular articles.

I received a Ph.D. in economics from Stanford University and an S.B. in economics from the Massachusetts Institute of Technology. I wrote my dissertation on how to measure technological change.

A copy of my curriculum vitae is attached as Appendix A.

III. Global economic growth in the past generation has been more profound than any in prior history, and innovation in the information sector was at the core of that growth

For much of human history, most people lived lives that were--in the words of Thomas Hobbes--nasty, brutish, and short. And for all too many people, life was hopelessly impoverished. Hunger, starvation, and depravations of all kinds were unexceptional.

The history of poverty is neither ancient nor is it today eradicated. According to the World Bank, in 1981, more than 41% of the world's population lived in what can only be described as abject subsistent poverty.[1] Yet, by 2013, the World Bank found that fewer than 11% of the world's population lived in this form of poverty, and the rate is projected to fall further. While having hundreds of millions of people living at subsistence remains an unsolved challenge, over the past few decades, 30% of the world's population, billions of people, moved up the income scale, almost certainly the largest mass increase in income in history. What happened during those roughly 30 years, approximately one generation?

There are many explanations, from the fall of communism to the opening up of markets in China, India, Africa, and other parts of the world to developments of new medical technologies and new agricultural breakthrough.

All of these explanations and more are important to understanding the past generation, but I want to focus on one issue that I find to be central to recent economic development: the information sector. When the economic history of the past generation is

[1] The World Bank's poverty line was set at less than $1.90 per day in 2011 purchasing power parity. This is far below our federal government's poverty line.

written, I believe it will be called the golden age of information and communications, and the United States was and remains at the center of that golden age.

In 1981, hardly anyone in the world, no matter how wealthy, had mobile wireless technology or access to the Internet. These technologies did not meaningfully exist. One could not purchase them at any price. Today, no matter how poor an individual, the vast majority of people in the world have access to mobile services, and purchase them at low and even no cost. Most people also have some form of direct access to the Internet or know someone who does.

I am not suggesting a single direct causal relationship between the emergence of new information technologies and the end of poverty. Improvements in information technology have, nonetheless, contributed to better education, improved business operations, enhanced agricultural production, better personal communications, and other factors all of which disproportionately favor low-income individuals. I am suggesting, however, that one of the greatest economic events in history, the emergence of much of the world's population from living at or near the subsistence level, has coincided with the development and global adoption of wireless services and the Internet. Today, once an individual has met basic needs of food, clothing, shelter, she tends to choose to purchase wireless services and Internet services, services that even the richest person in the world could not purchase a generation ago.

IV. The United States played a pivotal role in innovation in the information sector. Important factors included: increased protection of property rights; a lighter regulatory approach; and an emphasis on competition.

The extraordinary contribution of the United States over the past generation to fight global poverty and to enhance global welfare is not properly measured just in

dollars of foreign aid. Rather, it is better measured in the creativity of Americans and American businesses to develop new technologies and in the generosity of our government to make many of those technologies available to the world, free of charge. For example, in the 1990s the Clinton Administration opened up the Internet and Global Positioning Service (GPS) free of charge both to the United States to the world. They soon became two of the most widely adopted technologies in history. Even without the generosity of the American government, these technologies would have emerged eventually, but at higher cost and substantial delay.

New information technologies contributed not just to global economic welfare but to American economic growth as well. By my calculations, the information sector in the United States disproportionately contributed to economic growth in the United States, accounting for 19% of GDP growth from 1997-2002 and 9% of GDP growth from 2002-2007, substantially greater than its less-than-4% share of GDP.

Of course, much of the benefit of innovation in the information sector is not fully captured in GDP calculations because of the rapid and substantial changes in the nature of information services.

The five largest corporations by market capitalization in the United States are all in the information sector: Amazon, Apple, Google, Facebook, and Microsoft. They are also among the largest corporations in the world. These are all innovative companies, and together with smaller companies in the information sector, all have contributed to innovation and economic growth in America. None of these major companies existed in 1981. Scores of other publicly traded companies compete in the information sector, most founded since 1981. Countless private companies and startups compete in this sector. Ask

a twenty-something in America or anywhere around the world where he or she wants to work, and the answer likely is private company in the information sector. These new companies have provided the world with new technologies and have captured the imagination of the next generation.

Why did these companies develop in the past generation and not before? And why did they develop in the United States and not elsewhere? Some might point to extraordinary entrepreneurs and technologists such as Bill Gates, Jeff Bezos, Steve Jobs, Sergey Brin, Larry Page, and Mark Zuckerberg. Others might emphasize critical technologies developed before 1980 that enabled the further development of the information sector. No doubt, these and other factors are important.

But great entrepreneurs are born in every generation in every country. What made the information sector in the United States over the past generation different? Consider what Amazon, Apple, Google, Facebook, and Microsoft and scores of smaller companies have in common. They were all founded in America, and they all benefitted from three conditions that changed in the information sector in America in the past thirty years: clearer property rights in the information sector; a lighter regulatory touch; and more competition. Each of these factors was important to the development of the information sector in the United States over the past generation.

A. Clearer property rights

Property rights are at the core of most well-functioning economic systems. They certainly are at the core of improvements in the information sector. We can see them in clearer property rights for licensed spectrum, unlicensed spectrum, and intellectual property for software.

Licensed spectrum -- Before 1981, wireless spectrum was largely under the control of the federal government. Broadcasters had broadcast licenses under frequent threat of non-renewal. Other forms of commercial licenses were few in number and relatively undeveloped. Beginning in the 1980s and continuing through today, the Federal Communications Commission (FCC) provided greater clarity for licensed spectrum, adopting property rights concepts consistent with those advanced in the 1959 by future Nobel Laureate Ronald Coase.

In 1993, Congress granted the FCC authority to auction spectrum licenses eventually leading to more than 100 spectrum auctions over the past 25 years. The economic value of these auctions is not in the receipts raised but in the rationalization of use and ownership of spectrum licenses leading them to be put to have higher-valued uses. As I have reported, spectrum licenses in the United States have obtained much clearer property rights, but still further to go to obtain full property rights, and clearer property rights would significantly contribute to innovation and economic growth.

As slow as were the development of property rights in licensed spectrum in the United States, they were more rapid than in other countries. With few exceptions, licensed spectrum was put to use in the United States before it was in other countries. The value of licensed spectrum with property rights is substantial.

Unlicensed spectrum -- The concept of unlicensed spectrum did not exist in 1981. In the late 1980s, the FCC adopted rules relaxing the review of new low-energy equipment and new applications. The adoption of unlicensed rules unleashed a wave of new technologies ranging from Bluetooth to WiFi. Unlicensed technologies are used in most consumer electronic devices. Unlicensed spectrum today carries more data than

licensed spectrum. Unlicensed spectrum has substantial elements of property rights and has contributed to innovation, economic growth, and consumer welfare. Other countries have largely followed America's lead in unlicensed spectrum

Intellectual property – In 1981, for most purposes, packaged software did not exist. Software was largely proprietary and developed on an *ad hoc* basis. The software industry became a critical component of the information sector, and the development in the 1980s and 1990s of the software industry depended critically on intellectual property laws. The software industry developed largely in the United States in part because of strong intellectual property laws.

B. A lighter regulatory touch

Before 1981, the development of a robust information sector was hardly the primary purpose of federal regulators. The regulatory process was used, wittingly or not, to delay new technologies. For example, the first application for a cellular technology was in the 1950s. It was delayed for near 30 years before finally being accepted. The estimates of the consumer welfare loss from the delay are substantial.

Beginning in the 1980s and 1990s, the federal government led by Congress saw the importance of having government not impede new technologies. Perhaps most famously, politicians of practically all political affiliations in the mid and late 1990s embraced the slogans "Do Not Tax the Internet" and "Do Not Regulate the Internet." There was a clear understanding that taxation and regulation could harm the nascent Internet, a technology worth protecting from government interference.

Despite many problems associated with the combination of powers, the FCC began in the 1980s and 1990s to see itself as trying to get out of the way of new

technologies. In a series of rulemakings, the FCC consistently relaxed various regulations of telecommunications services. So too did various state regulatory commissions.

The FCC had a conscious effort not to regulate the Internet and not to regulate online companies. Four important decisions included the following:

(1) no origination or termination fees on Internet traffic;

(2) no preference or requirement of certain technological standards;

(3) no governmental curating of content or blocking websites; and

(4) no governmental use of the Internet to spy on Americans.

In contrast, other countries have attempted to regulate prices of Internet traffic, or to impose technology standards, or to block specific websites, or to spy on their citizens. These efforts have had harmful results and have hindered the development of the Internet in those countries.

Beginning in the 1990s, the American government consciously tried to remove impediments to the development of new information sector companies that now compete in both the United States and around the world. Recent concepts of network neutrality regulation and privacy regulation have, for the first time, threatened to lead to substantial federal regulation of the Internet.

C. Competition

One of the keys to any successful economic system is competition. Competition weeds out poor performance. Competition leads to lower prices for consumers and a wider array of choices. Competition was one of the central themes of the Telecommunications Act of 1996. Prior communications laws and regulations had

limited the number of telephone companies, cable companies, wireless companies, etc. The limited number was often *one*, a monopoly. Under the Telecommunications Act of 1996, statutory and regulatory monopolies were prohibited. Regulators were instructed to remove barriers to competitive entry.

Competition in American markets is primarily protected by antitrust law. Both the Department of Justice and the Federal Trade Commission have been active in markets in the information sector to protect the American consumer.

The competitive environment in the United States facilitated the expansion of the information sector. With competitive communications, new information companies had multiple competitive networks to develop new services and to reach customers. This competition in the United States almost certainly facilitated the development of the information sector.

Other countries have largely followed the United States on competition policy but with a substantial lag and with more restrictive rules on foreign investment and ownership. Well into the 1990s, most other countries had telephone companies that were partly or entirely owned by the national government. Private ownership of telecommunications networks, and private competition, had previously been proscribed. Today, the competitive framework of the United States is widely adopted around the world.

V. Despite early receptivity to the Internet, governments in other countries today are threatening the further development of the information sector

It would be comforting to report that all of the positive developments over the past few decades for the information sector, and their contributions to innovation and

growth in the United States and around the world, are likely to continue. The information sector is vulnerable to attack, and with it much of innovation and economic growth in America.

Perhaps the simplest index of the health of industry can be found—or, rather, not found in Washington. We have no Internet Regulatory Authority. We have no single agency responsible for regulating the information sector or the Internet. That absence is an American strength.

During the 1990s, other countries largely followed this American approach. The Internet spread internationally and was largely unregulated. The information sector is today the primary area of American commercial competitiveness in international markets. The information sector globally distributes information and entertainment, and much of the most popular forms are American in origin: American music, American videos, American software, and American technology.

But perhaps the most important American product distributed by the information sector is a simple American ideal: innovation is rewarded. Young people in America and around the world see the Internet and the information sector as tangible proof that the American ideal can work. Young people in America and around the world seek to work in the information sector in large because of faith in the American ideal and because of a hope that the American ideal can triumph over lesser ideals, including those that seek to limit innovation and to steal its reward.

The information sector globally is under attack. Over the past 15 years, many countries have steered towards destructive regulation of the Internet and the information sector. Many governments around the world have lessened property rights in the

information sector, have adopted punishingly stiff regulations, and have blocked competition. Some governments curate Internet content, steering some web sites to consumers and blocking others, and generally discouraging use. Some governments use the Internet to spy on their own people, further discouraging use. Some government use the Internet to engage in organized cybercrimes, stealing information, attacking innocent Internet users, many of them in America, and causing disruption and chaos everywhere. Some countries block American companies from offering services. Some countries use the Internet to facilitate piracy of intellectual property, much of it American. In international forums, many governments advocate an international regulatory body, possibly housed in the United Nations, to regulate the Internet.

These misguided efforts limit the prospects of the information sector in other countries. It would be naive to assume that these attacks on the information sector in other countries also do not spillover effects: they harm innovation in America; they reduce our economic growth. We should not imitate the bad policies abroad. The simple formula of clear property rights, reduced regulation, and competition unshackled the information sector in the United States in the past. The simple formula can continue to work in the future. This formula yields economic growth in America and the foundation to preserve the American ideal for countless individuals in America and around the world: innovation is rewarded.

Statement before the Joint Economic Committee
On "How the Innovation Economy Leads to Growth"

Innovation and Growth

Today's Opportunities and Challenges

Michael R. Strain
Director of Economic Policy Studies
John G. Searle Scholar

April 25, 2018

Chairman Paulsen, Senator Heinrich, and Members of the Committee, thank you for the opportunity to appear before you today to discuss innovation and economic growth. It is an honor.

ECONOMIC GROWTH IS CRITICAL

Economic growth drives increases in living standards and improves quality of life. A simple examination of the fruits of economic growth over the past two centuries — dramatic reductions in child mortality rates and poverty rates, significant increases in leisure time, longer lifespans, access to modern education and medical care — demonstrates what growth can do for individuals and societies. It has been discouraging to see some downplay the importance of economic growth in the public square. Imagine if our forefathers had done the same. Public policy is rightly concerned with increasing the rate of economic growth. Indeed, it should be among Congress' top concerns.

HOW ECONOMIES GROW

Economic output is a function of economic inputs. The growth rate of output, therefore, is determined by how quickly capital and labor grow, along with technology and the skill and knowledge with which factors of production are employed. Especially over longer time horizons, the most important driver of growth is innovation. And fundamentally, innovation is driven by letting loose the creative power of individuals to invent new and better ways of producing goods and services and, of course, new goods and services themselves.

FOSTERING INNOVATION

How can Congress foster innovation? One important way is to improve the skills of workers, helping to enable individuals to innovate. Education reform designed to teach twenty-first century skills is critical. A stronger emphasis on work-based learning for workers with high

school degrees is critical. And, in my view, increasing the number of highly skilled immigrants allowed to live and work in the United States is critical as well. Immigrants start businesses at a higher rate than native-born workers.[1] Perhaps more importantly, businesses in science and technology industries are disproportionately likely to be founded by an immigrant.[2] Many of the most innovative companies in the United States were founded by immigrants.

Government has a role to play in supporting the basic research that innovation requires. Two important ways government supports innovation are through funding basic research and producing the economic and social statistics required by businesses, researchers, and policymakers. It is critical that Congress not step back from these responsibilities.

Beyond encouraging innovation through increasing skills and supporting basic research, there is a wide variety of actions government can take. Avoiding excessively high tax rates, reducing regulation and other barriers to technological progress, and maintaining a posture of openness to the rest of the world through international trade are just some of the ways public policy can support innovation.

THREATS TO INNOVATION

Congress can also foster innovation by helping to create and enforce an appropriate regulatory environment. Likewise, imprudent regulation can stifle innovation, slowing economic growth and the rate of improvement of living standards.

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[1] Immigrants are more than twice as likely as those born in America to start a business; see Robert Fairlie. "Open for Business: How Immigrants Are Driving Small Business Creation in the United States," The Partnership for a New American Economy, August 2012.

[2] One fourth of all technology and engineering companies had at least one immigrant cofounder between 2006 and 2012; see "The Economic Case for Welcoming Immigrant Entrepreneurs," Entrepreneurship Digest, Ewing Marion Kauffman Foundation, September 2015.

I have been quite concerned about imprudent regulation recently in the conversation around "Big Tech." It has been common to hear calls from both the political left and right to break up major technology firms using the government's antitrust powers.

In my view, such action would be a major policy mistake.

For the past half century the federal government has followed the best standard that experts have crafted to identify anticompetitive behavior: consumer welfare. More specifically, when deciding whether a firm is hurting competition, the following questions should be asked: Is the company reducing the welfare of consumers by pushing up the prices consumers face, and/or by reducing the quality and variety of products and services consumers enjoy?

This antitrust standard stands in contrast to a different view, which rests on the presumption that large and powerful companies should be suspect because of their size, under the assumption that with size comes undue economic power and a lack of competition.

I would highlight three primary reasons why latter view is inferior to the consumer welfare standard. First, it is much more vague and harder to define. This vagueness invites regulatory mischief at worst. More than that, though, is the concern that due to its vagueness regulators might be swayed more by the public debate around a particular company than by relatively more objective metrics (keeping in mind that there is always a large subjective element to determinations under any standard).

Second, the view that is suspicious of size ignores the good things that come from size. Economies of scale allow companies to produce goods and services more efficiently, at a lower cost, than relatively smaller firms. These efficiencies can take many forms, including more specialized management and production techniques.

Third, focusing on size distracts regulatory attention from consumers. This argument is circular. It is equivalent to asserting that consumer welfare should be the regulatory goal in a normative sense.

Big Tech has significantly increased consumer welfare. Consider prices. Many products are offered to consumers free of charge. For example, Google searches, Gmail, Google-hosted websites, Facebook accounts, and Twitter accounts are all free. Amazon does not sell its products at a price of zero, but it has significantly reduced the prices faced by consumers for many products. Some even argue that Amazon is reducing the rate of consumer price inflation for the overall economy.[3]

Now consider product quality and innovation. The services mentioned above are remarkably innovative. In addition to them, for example, Apple first put an entire music library into the palm of our hands and then put a computer in all our pockets.

While it is very clear that Big Tech is advancing innovation and consumer welfare today, it is reasonable for regulators to ask whether its actions today might stifle innovation and consumer welfare in the future. In my view, there is little evidence to support this concern. Major technology companies spend significant sums of money on research and development for new products—i.e., on fostering innovation. Alphabet, the parent company of Google, spends sixteen percent of revenue on R&D. Facebook spends twenty-one percent. Microsoft spends fourteen percent. These ratios are far higher than for other companies. For example, General Motors, General Electric, Procter and Gamble, and AT&T each spend less than five percent of revenue on R&D.[4]

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[3] This is often referred to as the "Amazon effect." See, for example, Mark Whitehouse, "Amazon Might Help Explain the Inflation Mystery," *Bloomberg View*, 16 October 2017. (Disclosure: I am a Bloomberg View columnist.)
[4] Greg Ip, "The Antitrust Case Against Facebook, Google, and Amazon," *The Wall Street Journal*, 16 January 2018.

The argument that Big Tech is a threat to innovation and consumer welfare in the future must also contend with the amount of churn in the technology industry. It was not long ago that the dominant web browser was Netscape, not Google; the dominant email service was not Gmail; and America Online was the dominant ISP. It is imprudent to assume that Google, Facebook, Apple, Amazon, and other tech giants will be dominant in perpetuity.

The public conversation also seems to misrepresent the actual dominance of these companies in the present day. For example, despite the concern about Amazon's dominance, online sales represent less than ten percent of total retail sales.[5] Walmart's revenue is more than twice that of Amazon's.[6]

In summary, I do not view Big Tech as a threat to consumer welfare or innovation, and I am not convinced by arguments that antitrust action is required to advance those goals. Instead, Big Tech is advancing consumer welfare through offering consumers a wide variety of high-quality products at low (and sometimes zero) prices. In addition, Big Tech is advancing consumer welfare and innovation in the future through high amounts of spending on research and development, which will fuel innovation for the future.

And the innovation created by Big Tech will fuel faster economic growth and higher living standards for American families.

CULTURE

I will close with brief remarks on the importance of culture. Social attitudes that value hard work and openness to new ways of doing things are critical for fostering innovation, growing the economy, and increasing living standards. The same is true for social capital, which affects trust and cooperation both in and out of economic life. Politics and policy are largely

[5] U.S. Census Bureau, Quarterly Retail E-Commerce Sales, Fourth Quarter 2017.
[6] Wal-Mart's 2018 revenue was $500.34B. Its 2017 revenue was $485.14B. Amazon's 2017 revenue was $177.87B.

downstream from culture, but it is an overstatement to argue that they don't affect culture. Where innovation comes from is largely a mystery. But a hypothesis worth taking seriously is the intersection of strong institutions and a culture that supports risk taking, skill accumulation, hard work, and creativity. Many public policy decisions in a wide array of domains subtly and indirectly affect these values and dispositions. The total effect of those decisions might be significant.

CONGRESS OF THE UNITED STATES
JOINT ECONOMIC COMMITTEE
Hearing on "How the Innovation Economy Leads to Growth"
Hart Senate Office Building
April 25, 2018

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Thank you Chairman Paulsen and members of the Committee for the opportunity to testify on this important issue.

Over my career, I have had the good fortune of working in each of the four corners of the innovation economy's ecosystem. Early in my career I was a practicing innovator and earned several patents as semiconductor engineer and later as a scientist in optical communications. I was introduced to the interstices of innovation policy as a young staffer in President Reagan's White House Science Office. And today I'm engaged in the other two aspects, in finance with a tech venture fund and as an analyst.

I mention these four parts of the innovation economy to note that there is – or at least there used to be -- a common thread that ran through all of them, which is that far more innovation lies in our future. That conviction is no longer accepted by some analysts and academics. This divergence has important implications because what we believe about the future directly impacts planning and policy decisions being made today.

In dispute is not whether more innovation in general is coming, but whether or not the innovation on the horizon is truly significant; i.e., significant, enough to re-animate the kind of economic growth we have experienced in the past. If one accepts the proposition that innovation is now yielding merely incremental advances over current practices and products, or that it is dominated mainly by such things as better apps and entertainment, then one logically reaches the pernicious conclusion that we are in a mature economy that must accept a so-called "new normal" of far slower economic growth.

Policymaking under the new normalist paradigm logically becomes a kind of *de facto* palliative care for an ostensibly mature late-stage society.

The new normalists don't propose that technology will stop causing disruptions similar to those we're witnessing now around, for example, social media and the Internet's impact on politics and culture. The new normalists suggest instead that the disruptive features of technology are a kind of froth on top of a new paradigm of permanently slower overall economic growth. As evidence, the new normalists make the points that over the past decade or so, GDP growth has been anemic and, more important, a critical underlying driver of the economy, U.S. productivity growth, has been low and stagnant for nearly 15 years.

The closest economists get to having a law of physics is in the truism that increasing productivity is the primary force driving economic growth. An enormous body of scholarship has been devoted to studying productivity: Providing a coherent theory around productivity, technology and growth earned Robert Solow a 1987 Nobel Prize. Absent foundational innovations, there is no prospect for a return to higher productivity growth. And without that, America *does* face a dismal economic future.

The problem, however, with the thesis that America is facing a new age of secular stagnation is that its adherents misread the implications of the recent record of slow productivity growth. Set aside important co-factors that can suppress innovation (especially unfriendly tax and regulatory policies). The primary reason for recent lagging productivity growth is that we have been living through an interregnum between great technological cycles. Radical changes in technology don't emerge in convenient continual steps, but instead burst forth episodically.

History offers many examples of the episodic character of innovation at the scales that move economies. The underlying technological driving forces always seem obvious in hindsight, but are rarely anticipated in advance by economists and forecasters.

In order to illustrate history's episodic pattern for foundational innovation, consider a recent example in energy domains. Then we can look for a similar underlying pattern in two other domains where revolutions currently seem absent: manufacturing and healthcare. These latter two sectors constitute 30% of the American economy.

The essence of the policymaker's dilemma when it comes to making plans that depend on assumptions about productivity is that those assumptions are necessarily based on *forecasts* about technology. I will resist the temptation to dwell on that fact that when it comes to forecasting, the track record from most pundits and especially economists is dismal at best.

The quasi-profession of forecasting may be a dubious science, but it is a serious business nonetheless. A particularly relevant aphorism about forecasting originated

with physics Nobelist Dennis Gabor who wrote in 1963: "The future cannot be predicted, but can be invented."

But back to energy: as analysts and policymakers around the world now know, we have recently experienced radical technological progress in energy technologies.

Last year marked the 40th anniversary of legislation establishing the Department of Energy. Its core mission was to find technologies to replace oil and natural gas, and to reduce the use of both those fuels. For decades the accepted wisdom was that there was no prospect for technologies that could affordably produce hydrocarbons at the scale society would need in the future. In other words, in economic terminology: hydrocarbon technology productivity had stalled out.

We now know that dismal forecast was wrong. A new technological approach, unlocking hydrocarbons in America's vast shale fields, turned out to be astonishingly productive. Those on the front lines of that revolution were rarely, if ever, visible in the public and policy discourse. All eyes were on the forecasts of technology alternatives favored by the DOE and others. Meanwhile, over the past decade alone, U.S. shale technology has delivered the fastest and biggest addition to world energy supplies that has occurred in history, anywhere and from any energy source. Shale oil and gas added 2000% more to U.S. energy supply over the past decade alone than have solar and wind combined.

But the energy technology forecasts of yesteryear led to a cumulative $500 billion in government spending over four decades in the pursuit of technologies to replace hydrocarbons. Biofuels production did grow, rising from 0.1% of America's energy supply in 1977 to about a 2% now. Similarly, the combined energy production from solar and wind also rose from near zero in 1977 to about 3% of today's total U.S. energy supply. Meanwhile oil and gas meet nearly 70% of U.S. energy demand.

I note that those few forecasters who anticipated what would actually happen were at that time generally ignored or viewed as engaged in "old think" or in the "pockets" of entrenched industries. (As some on this Committee know, my written record shows that I was counted amongst those in that history's minority.)

In getting technology forecasts wrong circa 1977, the economists and energy pundits then were in good company. Back in the 1970s, economists were also puzzled by an overall productivity collapse similar to the one we have recently experienced. There were many forecasters back then deeply worried about economic stagnation – and even the dreaded "stagflation" of inflationary pressures occurring simultaneously. It is instructive to note, however, that the 1976 economic report to Congress by the Council of Economic Advisers, chaired by Alan Greenspan,

did not contain the word "computer." Missing the computer revolution in economic forecasts at that time was understandable, but it was no small error.

The lessons one should derive from the history of energy technology are two-fold. The first is that noisy public debate and aspirational forecasts can hide the real underlying trends. The second is that what appears to be an end to innovation is often a pause between eras as engineers and industries perfect and begin to adopt new foundational technologies.

The question now is what predictive technological "signals" are we missing today, signals hidden in the media "noise" about the demise of manufacturing and the inevitability of cripplingly higher healthcare costs. The energy sector is important, but manufacturing and healthcare are, respectively, 1.5-fold and 2-fold bigger parts of the economy.

With regard to manufacturing, the current narrative is that productivity gains are nearly maxed out and more automation will merely add efficiency that will displace more workers in a declining domain. And with regard to healthcare, a different manifestation of technological pessimism is inherent in the forecast that consumer 'demand' for healthcare will grow far faster than the efficacy or – again in economic terms -- the productivity of healthcare services.

In both cases, today's pessimists are mistaking, again, an interregnum between technological eras as evidence of stagnation in foundational technology innovations.

Start with manufacturing. The idea that a modern nation's share of GDP and employment in manufacturing will necessarily decline is negated by the examples of Germany and Japan which have *not* experienced the sharp declines seen in America. Evidence points to the decline in U.S. manufacturing over the past decade coming in large measure from the dual insult of high taxes and a huge increase in the regulatory state.

At the same time it has been fashionable to blame automation for a decline in manufacturing employment. But here it's important to note that the data show manufacturers' overall spending on information technology has actually been flat or even *decreased* over the past decade. IT spending as a share of revenue in manufacturing is only one-fourth that seen in the information-centric sectors: media, banking, education and insurance. The real challenge for manufacturing is that it is still *under-invested* in IT, and has yet to sufficiently adopt new productivity-driving technologies.

But sensors, computers and communications have finally improved enough to meet the far more demanding metrics of the industrial world, as compared to the

information-centric domains -- social media, news, entertainment, finance, etc. -- where info-tech has made its greatest gains so far. Excitement is finally starting to build in some corners of Silicon Valley about bringing information tools into the manufacturing sector to make everything "smarter" and more efficient. That will happen, but arguably even more important are the contemporaneous 'hidden' revolutions in new kinds of manufacturing machines, and radically new kinds of materials.

A materials revolution is emerging akin to the dawn of the age of chemistry a century ago. The use of a high-performance computing combined with the so-called "materials genome" is ushering in an era of computationally designed materials. Not only will such things as new classes of ultra-high-strength and lightweight materials emerge, but also entirely new materials that enable biocompatible (even consumable) sensors and computers, and the commercialization of so-called metamaterials. The latter exhibit properties that don't exist naturally and unlock the ability to create entirely novel kinds of products.

Along with the materials and industrial-information revolutions, we are seeing the maturation of radically new kinds of manufacturing machines. For example, the commercialization of 3D printers will enable a kind of manufacturing that could best be termed "mass customization" rather than just mass production. 3D printers also allow the fabrication of components and devices impossible with conventional machines.

At the same time, we are also seeing industrial robots finally emerge that can take on truly complex or highly variable tasks. Up until now, robots have been deployed primarily in a few industrial sectors, dominatingly automotive where the tasks are relatively simple and repetitive. Other industrial sectors will soon gain robot-driven productivity benefits as industrial robots, which can tackle more complex and varied tasks -- especially so-called "cobots" which work safely and intuitively alongside humans – now begin to emerge.

These technological trends will accelerate the shift of manufacturing away from low-cost labor to high-skilled labor and high-value markets. Improving American manufacturing competitiveness could not come at a better time. The conventional wisdom that automation will offer economic growth but reduce industrial employment is offset by the magnitude of the looming demand for manufactured goods just about to emerge.

The fact is the global demand for manufactured goods is on the cusp of the greatest expansion in history. The world's GDP is forecast to expand by nearly twice as much over the next 20 years as it did in the past 20. This means at least twice the growth in demand for everything from cars and aircraft, to tractors and chemicals, to

clothes and computers. Rising productivity means, by definition, greater competitiveness; and those countries that make these leaps will enjoy precisely the same benefits that productivity gains have yielded throughout all of history: more economic growth and more jobs.

Turning now to healthcare, the underlying technological patterns are similar to those in manufacturing.

Start with the fact that healthcare productivity, measured in economists' terms again, i.e., value added per labor-hour, has been flat for 15 years. The absence of progress in labor productivity is precisely why costs are rising as demand increases. Other than rationing, technology innovation is the only path to lower-cost and more high-quality healthcare.

Information systems can add valuable efficiency to administering healthcare services, or the management of records and insurance. But what is really required is a kind of foundational progress in the efficacy – i.e., productivity -- of diagnostics and therapeutics.

In healthcare we are also at an interregnum since the key enabling technologies are relatively new and take time to mature and be fully absorbed within the ecosystem. Qualification takes time when it comes to hardware and humans. And, as with manufacturing, healthcare domains are just now seeing the practical emergence of new kinds of materials and new kinds of machines against a backdrop of profoundly more powerful computing.

It is well known that accurate and quick diagnosis is one of the critical aspects of healthcare. Here we see the prospect for both radical advances in efficacy as well as the democratization of diagnostic tools arising from new materials, new communications and high-performance computing. Diagnosis starts, of course, with obtaining critical data.

We are about to see explosive growth in access to biological information because of the rapidly evolving and new field of bioelectronics. We are well along the path to commercial bioelectronics that are body-compatible, implantable and even digestible. Once widely deployed, bioelectronics will rival in scale the traditional silicon electronics industry and offer a tsunami of heretofore unavailable data. The FDA has already approved a number of the key components.

Rather than inserting instruments or indirectly or episodically measuring various biological states, wireless bioelectronics can directly monitor conditions continuously. For post-operative monitoring, for example, these new materials allow embedded infection-monitoring sensors that eventually dissolve just as

stitches do, and allowing a kind of monitoring heretofore impossible thereby reducing patient complications and risk, as well as lowering both direct costs and the risks of later complications and indirect costs.

While it takes time for FDA approval of intrusive technologies of any kind, consider in the meantime the easier-to-deploy sub-class of external bio-compatible wearables (e.g., bandaids as sensors) that are already on the way to becoming a multi-billion-dollar industry with far-reaching potential for healthcare 'productivity'. Apple, for example, is well aware of the fact that features inherent in, or that can be added to, an iPhone constitute implicit if not explicit classification as a medical device. There are profound implications to the prospect of nearly every citizen possessing a useful diagnostic device.

But coming faster are advances in professional diagnostic tools, both those in the laboratory and those on the front lines of healthcare. These new devices are made possible by precisely the same suite of sensors, CPUs, communications, and materials technologies that are spreading throughout industrial ecosystems. The recent XPrize award for a portable diagnostic tool provides a dramatic example of the emergence of diagnostic devices that were recently only the stuff of science fiction.

In 2012 Qualcomm, a company better known in IT rather than medical circles, partnered with the XPrize Foundation to offer $5 million for a team able to emulate the "Star Trek" tricorder. For those not SF cognoscenti, the spaceship's doctor would wave a handheld tricorder over a patient to obtain immediate diagnoses. That notional prize – "to develop developed a mobile device able to diagnose 13 health conditions while continuously monitoring five vital signs" – was awarded a year ago to a Pennsylvania startup. That XPrize and the proliferation of smartphone health apps and tools are emblematic of deep secular shift emerging in medical diagnostic technologies.

Then there is the promise of genetic engineering. This domain too is fundamentally information-centric using rapidly advancing classes of gene-mapping machines and high-performance computing that are becoming ever less expensive. It is no longer science fiction, even though it is early days, to think about the idea that algorithms could develop new drugs or simulate preliminary field trials, even clinical trials that are hyper-personalized.

Similarly, a new discipline is emerging around the potential to emulate a trend that started in industrial domains where one could create a digital twin for an individual (or a machine or process). As it becomes easier and cheaper to obtain real-time information about an individual's health and biological conditions, that information can be used by a computer model of that individual to assess and even diagnose

health conditions in real time. While that possibility is still in the future, the diagnostic and information tools that will ultimately lead there are already starting to become practical.

And all of this says nothing about other revolutionary healthcare technologies 'hidden' in the technical literature today. Of particular interest is the emerging class of practical robots, in particular cobots I mentioned earlier, that work collaboratively with people. Surgical cobots such as the Da Vinci have been around for a number of years; but many more are coming, unlocking far more potential for hyper-precise and minimally invasive surgery. Cobots will be particularly helpful in eldercare and rehabilitation. FDA recently approved, for example, a cobot in the form of a wearable exoskeleton for more effective ambulatory rehabilitation.

We are, in short, on the cusp of technology-driven "productivity" gains in healthcare that are unprecedented in history. These gains will come from tools and techniques that we know are undergoing rapid improvement and whose costs are declining. By definition, they epitomize precisely what is inherent in the definition of productivity – more output at lower costs.

Using technology to reduce or amplify human labor has been a central pursuit of humanity for all of recorded history. Productivity is central to economic progress. As economic historian Joel Mokyr has pointed out, technological innovation gives society the closest thing there is to a "free lunch." From the dawn of the industrial revolution, it has enabled the near-magical increase in the availability of food, fuel and many products.

Today we stand at the beginning of epoch-changing shifts in technologies relating to both manufacturing and healthcare. As history shows, such advances have never been predicted by economists. Instead they've been invented and propelled by innovators. We should look for evidence of the next great cycle of foundational innovation in the 'hidden' domains where innovators work, not where pundits and the media prognosticate.

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Governance Studies
at BROOKINGS

A Hearing of the Joint Economic Committee of the U.S. Congress
"How the Innovation Economy Leads to Growth"
April 25, 2018

Statement of Darrell M. West, Ph.D.
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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.

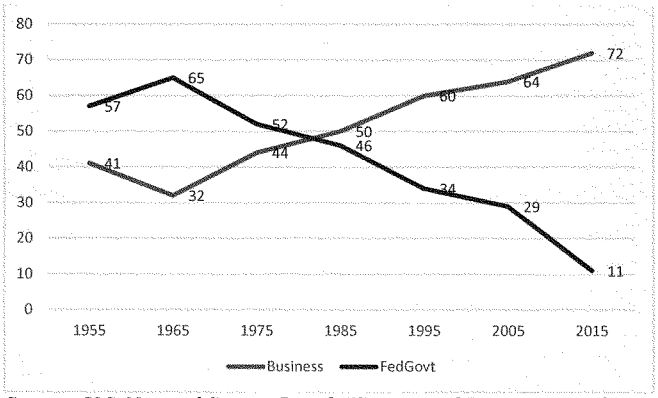
But these strengths do not mean the federal government should do little to facilitate the innovation economy. The internet represents one of the most successful government investments of all time owing to its origins as an Advanced Research Projects Agency communications tool known as ARPANET. NASA's 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

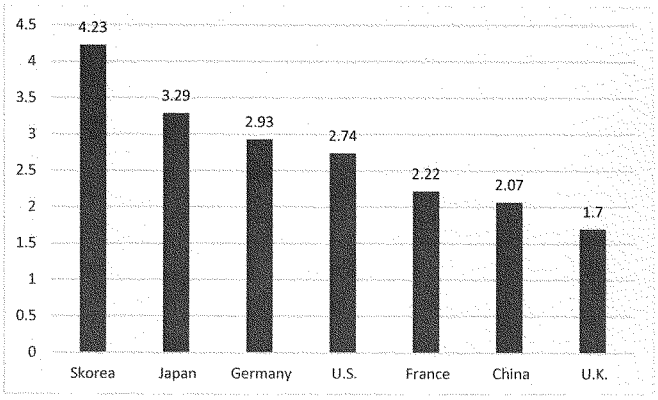


Source: U.S. National Science Board, "Science and Engineering Indicators," 2018, Appendix Table 4-1.

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

[1] National Science Board, "Science and Engineering Indicators", 2018.

[2] National Science Board, "Science and Engineering Indicators, 2018, Appendix Table 4-1.

[3] National Science Board, "Science and Engineering Indicators, 2018, Figure 4-7.

[4] National Science Board, "Science and Engineering Indicators, 2018, Figure 4-6.

[5] Greg Brockman, "The Dawn of Artificial Intelligence," Testimony Before U.S. Senate Subcommittee on Space, Science, and Competitiveness, November 30, 2016.

[6] Paul Mozur, "China Sets Goal to Lead in Artificial Intelligence," *New York Times*, July 21, 2017, p. B1.

[7] For additional details, see Darrell M. West and John R. Allen, "How Artificial Intelligence is Transforming the World," Brookings Institution report, April, 2018.

[8] Amir Khosrowshahi, "Testimony before the House Committee on Oversight and Government Reform Subcommittee on Information Technology," February 14, 2018.

[9] PriceWaterhouseCoopers, "Sizing the Prize: What's the Real Value of AI for Your Business and How Can You Capitalize?" 2017.

[10] Dominic Barton, Jonathan Woetzel, Jeongmin Seong, and Qinzheng Tian, "Artificial Intelligence: Implications for China" (New York: McKinsey Global Institute, April 2017), p. 1.

[11] Darrell M. West, *The Future of Work: Robots, AI, and Automation*, Brookings Institution Press, 2018.

[12] Osonde Osoba and William Welser IV, "The Risks of Artificial Intelligence to Security and the Future of Work" (Santa Monica, Calif.: RAND Corp., December 2017), p. 7.

[13] Dominic Barton, Jonathan Woetzel, Jeongmin Seong, and Qinzheng Tian, "Artificial Intelligence: Implications for China" (New York: McKinsey Global Institute, April 2017), p. 7.

[14] Executive Office of the President, "Artificial Intelligence, Automation, and the Economy" and "Preparing for the Future of Artificial Intelligence."

[15] Darrell M. West and John R. Allen, "How Artificial Intelligence is Transforming the World," Brookings Institution report, April, 2018.

[16] Nancy Scolar, "Facebook's Next Project: American Inequality," *Politico*, February 19, 2018.

[17] Ian Buck, "Testimony before the House Committee on Oversight and Government Reform Subcommittee on Information Technology," February 14, 2018.

[18] Keith Nakasone, "Testimony before the House Committee on Oversight and Government Reform Subcommittee on Information Technology," March 7, 2018.

[19] National Center for Education Statistics, "Status and Trends in the Education of Racial and Ethnic Groups: STEM Degrees," 2017.

[20] Darrell M. West, "Technology and the Innovation Economy," Brookings Institution report, October 19, 2011.

[21] World Economic Forum, "Human Capital Report," 2016, Countries with the Most STEM Graduates.

[22] American Society of Civil Engineers, "Report Card for America," 2017.

[23] Monica Anderson, Andrew Perrin, and Jingjing Jiang, "11% of Americans Don't Use the Internet," Pew Research Center, March 5, 2018.

[24] Internet World Statistics, "Top 50 Countries with the Highest Internet Penetration Rates," 2016.

[25] Netflix, "Internet Connection Speed Recommendations," 2018.

[26] Roger Cheng, "5G Super Speeds Are Coming," *CNET*, March 2, 2018.

[27] Darrell M. West, Allan Friedman, and Walter Valdivia, "Smart Policy: Building an Innovation-Based Economy", Washington, D.C.: Brookings Institution Center for Technology Innovation, 2013.

[28] Federal Communications Commission, "Broadband Deployment Report," February 2, 2018.

[29] Darrell M. West, *The Future of Work: Robots, AI, and Automation*, Brookings Institution Press, 2018.

Who Becomes an Inventor in America? The Importance of Exposure to Innovation
Alexander M. Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John Van Reenen
NBER Working Paper No. 24062
November 2017
JEL No. E0,H0,J0,O3
http://www.nber.org/papers/w24062

ABSTRACT

We characterize the factors that determine who becomes an inventor in America by using de-identified data on 1.2 million inventors from patent records linked to tax records. We establish three sets of results. First, children from high-income (top 1%) families are ten times as likely to become inventors as those from below-median income families. There are similarly large gaps by race and gender. Differences in innate ability, as measured by test scores in early childhood, explain relatively little of these gaps. Second, exposure to innovation during childhood has significant causal effects on children's propensities to become inventors. Growing up in a neighborhood or family with a high innovation rate in a specific technology class leads to a higher probability of patenting in exactly the same technology class. These exposure effects are gender-specific: girls are more likely to become inventors in a particular technology class if they grow up in an area with more female inventors in that technology class. Third, the financial returns to inventions are extremely skewed and highly correlated with their scientific impact, as measured by citations. Consistent with the importance of exposure effects and contrary to standard models of career selection, women and disadvantaged youth are as under-represented among high-impact inventors as they are among inventors as a whole. We develop a simple model of inventors' careers that matches these empirical results. The model implies that increasing exposure to innovation in childhood may have larger impacts on innovation than increasing the financial incentives to innovate, for instance by cutting tax rates. In particular, there are many "lost Einsteins" — individuals who would have had highly impactful inventions had they been exposed to innovation.

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RESPONSE FROM DR. FURCHTGOTT-ROTH TO QUESTIONS FOR THE RECORD SUBMITTED BY REPRESENTATIVE MALONEY

1) Last year Alexander Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova and John Van Reenen released a National Bureau of Economic Research working paper titled, "Who Becomes an Inventor in America? The Importance of Exposure to Innovation."

This is not a theoretical paper. The authors create a dataset of 1.2 million inventors—defined as individuals who hold patents—and compare it to datasets of children with various characteristics.

The authors find that:

> **" . . . children's characteristics at birth—their socioeconomic class, race and gender—are highly predictive of their propensity to become inventors. Children born to parents in the top 1 percent of the income distribution are 10 times as likely to become inventors as those born to families with below-median income. Whites are more than three times as likely to become inventors as blacks. And 82 percent of 40-year-old inventors today are men. This gender gap in innovation is shrinking gradually over time, but at the current rate of convergence, it will take another 118 years to reach gender parity.**

In the second part of their analysis, the authors find that "exposure to innovation during childhood through one's family or neighborhood has a significant causal effect on a child's propensity to become an inventor."

In the third part of the working paper, the authors look at the impact of financial incentives on inventors' propensity to innovate. They state that their findings "imply that small changes in financial incentives will not affect innovation significantly."

What are the policy implications of the empirical findings in this paper?

Thank you for noting this important paper that focuses on the individuals who file patents. The paper finds that individuals who are exposed to innovation at an early age are more likely to patent in the future. This result may have some effect on teaching methods, particularly for mathematically gifted students.

I should note that patents are but one measure of innovation and but one form of intellectual property. Many individuals and businesses that are widely considered as innovative hold few if any patents.

Indeed, of the five largest corporations in America that I discussed in my prepared testimony—Amazon, Apple, Facebook, Google, and Microsoft—only Apple is heavily patent-oriented. The other companies hold substantial portfolios of patents, but their business models do not rely on them exclusively. Nor is having a patent-oriented business plan a guarantee of success. Businesses such as Kodak and Xerox had substantial patent portfolios, but nonetheless entered bankruptcy.

Still, I believe that the NBER paper has important results that may be relevant to education programs, particularly for mathematically gifted students.

Joint Economic Committee Hearing
"How the Innovation Economy Leads to Growth"
Questions for the Record for Dr. Michael Strain
Submitted by Representative Carolyn B. Maloney
May 4, 2018

1) In the past the high-tech industry has benefited greatly from the fact that workers often move from one company to another, taking their skills with them. It has been argued that this hybridization has been a significant factor in promoting innovation.

Yet some companies have tried to enforce noncompete agreements that restrict the workers' ability to take another job in the same industry. It is likely that tens of millions of technical professionals in the United States are asked to sign such agreements. Many workers that have signed noncompete agreements take career detours – they are forced to leave their field for two years or more, taking their skills and experience with them.

What is the effect noncompete agreements? Do they dampen innovation? Is this a substantial effect or an inconsequential one?

2) In your testimony you state that:

> "Congress can also foster innovation by helping to create and enforce an appropriate regulatory environment. Likewise, imprudent regulation can stifle innovation, slowing economic growth and the rate of improvement of living standards."

I would like to hear more about the first part of your quote. Can you give examples of how creating and enforcing regulations can foster innovation? Could you point to an example of under-regulation in which prudent regulations would foster innovation?

Michael R. Strain
Director of Economic Policy Studies
John G. Searle Scholar

May 14, 2018

Colleen Healy
Joint Economic Committee
United States Congress
Washington, D.C.

Dear Ms. Healy:

I am writing to respond to questions for the record, submitted to me by Representative Carolyn B. Maloney, regarding my testimony in the Joint Economic Committee Hearing, "How the Innovation Economy Leads to Growth." It was an honor to testify, and I'm happy to answer Rep. Maloney's questions for the record.

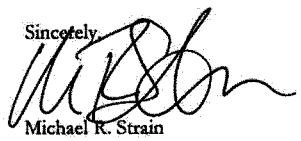
1. Noncompete agreements are surprisingly difficult to interpret. On the one hand, as you write, the economy benefits from knowledge workers having mobility across firms and industries. On the other hand, firms have a reasonable stake in keeping knowledge in house, particularly if that knowledge was generated in part by investment in human and physical capital on the part of the firm. If noncompetes were less common, then innovation might be encouraged due to mobility. At the same time, innovation might be discouraged because firms might be less willing to make important investments. This is an area that requires further study, but my current view is that on net noncompetes likely have an inconsequential effect on innovation.

   The current policy discussion around noncompetes is mostly focused on the low-wage labor market. There, I don't think innovation is much of a concern at all. But competition in the low-wage labor market and the welfare of low-wage workers are not enhanced by noncompetes.

2. For example, innovation can be fostered by regulations that protect property rights and that enforce the rule of law. This is a widely accepted view among economists. In addition, regulation that helps to make markets more competitive can foster innovation by increasing the pressure firms face to create new and better products. Beyond firms, regulation that helps individuals to acquire human capital might also help create innovation. A famous example of when underregulation led to less innovation is Standard Oil. The company was a major generator of patents at first, but once it achieved market dominance it become less innovative. The government eventually took action, and there is evidence that doing so led to an increase in innovative activity.

Thank you again for the opportunity to appear before the committee to discuss such an important issue. If there is anything else I can do for the committee, please don't hesitate to reach out.

Sincerely,



Michael R. Strain

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Joint Economic Committee Hearing
"How the Innovation Economy Leads to Growth"
Questions for the Record for Dr. Darrell West
Submitted by Representative Carolyn B. Maloney
May 4, 2018

1) Last year Alexander Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova and John Van Reenen released a National Bureau of Economic Research working paper titled, "Who Becomes an Inventor in America? The Importance of Exposure to Innovation."

   This is not a theoretical paper. The authors create a dataset of 1.2 million inventors – defined as individuals who hold patents – and compare it to datasets of children with various characteristics.

   The authors find that:

   > "... children's characteristics at birth -- their socioeconomic class, race and gender -- are highly predictive of their propensity to become inventors. Children born to parents in the top 1 percent of the income distribution are 10 times as likely to become inventors as those born to families with below-median income. Whites are more than three times as likely to become inventors as blacks. And 82 percent of 40-year-old inventors today are men. This gender gap in innovation is shrinking gradually over time, but at the current rate of convergence, it will take another 118 years to reach gender parity.

   In the second part of their analysis, the authors find that "exposure to innovation during childhood through one's family or neighborhood has a significant causal effect on a child's propensity to become an inventor."

   In the third part of the working paper, the authors look at the impact of financial incentives on inventors' propensity to innovate. They state that their findings "imply that small changes in financial incentives will not affect innovation significantly."

   What are the policy implications of these empirical findings?

2) Many CEOs have spoken out in favor of H1-B visas, claiming that they are essential because their companies have trouble finding enough qualified workers. They claim that their ability to innovate and to compete in world markets is partly dependent on being able to hire such talent. Highly innovative companies like Apple, Amazon, Google, Microsoft and others use H1-B workers.

Is there a way to tap the innovative energy of highly skilled foreign workers without displacing American workers? What should our long-term strategy for both fostering innovation and creating well-paying jobs?

3) In the hearing I asked you about the likely effect of noncompete agreements in the high-tech sector. Our time was tight and you did not have the opportunity to answer fully. Could you please elaborate on your assessment of the likely effects of noncompete and nondisclosure agreements on innovation? Is the effect a substantial or an inconsequential one?

Governance Studies
at BROOKINGS

A Hearing of the Joint Economic Committee of the U.S. Congress
"How the Innovation Economy Leads to Growth"
April 25, 2018

May 9, 2018 Remarks Extension by Darrell M. West, Ph.D.
Vice President of Governance Studies
and Director of the Center for Technology Innovation
Brookings Institution
Washington, D.C.

Chairman Paulsen, Ranking Member Heinrich, Representative Maloney, and members of the Committee. Thank you for the opportunity to extend my hearing testimony through written responses to Representative Maloney's questions.

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.

There are three questions where I would like to elaborate:

- Policy implications of the role of childhood background in becoming an inventor
- How to tap foreign worker innovation without displacing American workers
- Likely effects of noncompete agreements in high-tech sector

Implications of Childhood Background on Becoming an Inventer

In 2017, Alexander Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John Van Reenen published a National Bureau of Economic Research (NBER) working paper entitled "Who

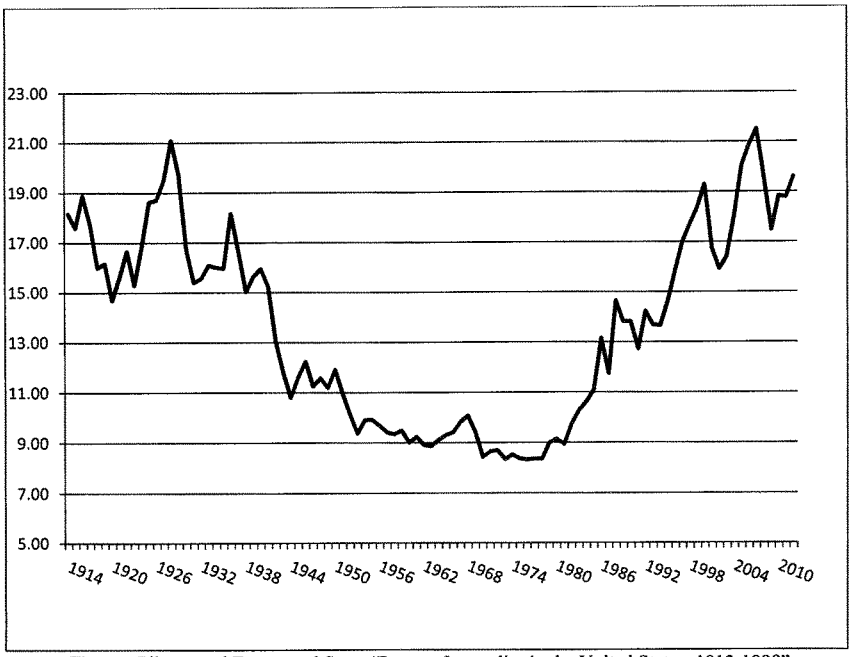
Becomes an Inventor in America? The Importance of Exposure to Innovation". It draws upon a data base of 1.2 million inventors and finds that:

> "... children's characteristics at birth -- their socioeconomic class, race and gender -- are highly predictive of their propensity to become inventors. Children born to parents in the top 1 percent of the income distribution are 10 times as likely to become inventors as those born to families with below-median income. Whites are more than three times as likely to become inventors as blacks. And 82 percent of 40-year-old inventors today are men. This gender gap in innovation is shrinking gradually over time, but at the current rate of convergence, it will take another 118 years to reach gender parity."[1]

In addition, the researchers argue that "exposure to innovation during childhood through one's family or neighborhood has a significant causal effect on a child's propensity to become an inventor." Finally, the authors look at the impact of financial incentives on inventors' propensity to innovate, and conclude "small changes in financial incentives will not affect innovation significantly."[2]

These empirical results have important policy implications. For starters, they highlight the importance of economic inequality in the innovation economy. If one looks at income inequality over the past century, it is much higher now than in the 1970s and 1980s, when the innovation economy took off. During those years, the upper one percent received less than 11 percent of America's income, much lower than the 19 to 21 percent typical of the past few years.[3]

Figure 1 Income Inequality in America, 1913-2012



Source: Thomas Piketty and Emmanuel Saez, "Income Inequality in the United States, 1913-1998" *Quarterly Journal of Economics*, Vol. 118, 2003, pp. 1-39. For 1999 to 2012 numbers, see the web page of Emmanuel Saez at http://emlab.berkeley.edu/users/saez.

The results of the NBER paper suggest that high inequality is detrimental to innovation as judged by the patent filings of inventors. Those who grow up without great wealth are far less likely to invent products and therefore contribute to the innovation economy. As noted in my book, The Future of Work: Robots, AI, and Automation, wealthy individuals have cumulative advantages in education, role modeling, and social networking that put them in a strong position for invention later in their lives.

For this reason, it is important to have policies that promote opportunity for young Americans. This includes:

- the earned income tax credit program which helps those below the poverty line to cover basic living expenses and childcare
- investment in pre-K programs so that young children get off to a good start and are able to develop basic skills
- fair and equitable tax policies that promote well-being and opportunity

- paid family leave so that parents have time to take care of new-borne babies
- health immunization programs to protect young children from dangerous diseases
- STEM programs that encourage women and minorities to get scientific degrees
- Improving digital access so people in underserved rural and urban areas can use the Internet and digital platforms
- Making sure anchor institutions in communities such as schools, hospitals, and libraries have high-speed broadband so they can provide economic development opportunities
- Enacting a solidarity tax on the top one percent to finance needed improvements in education, healthcare, workforce development, and social support

How to Tap Foreign Worker Innovation Without Displacing American Workers

Many CEOs have spoken out in favor of H1-B visas, claiming that they are essential because their companies have trouble finding enough qualified workers. They claim that their ability to innovate and compete in world markets is partly dependent on being able to hire such talent. Highly innovative companies like Apple, Amazon, Google, Microsoft and others use H1-B workers. Representative Maloney asked whether there is a way to tap the innovative energy of highly skilled foreign workers without displacing American workers and what our long-term strategies should be for fostering innovation and creating well-paying jobs.

Current law mandates that technology companies wanting to bring high skilled foreign workers to the United States have to advertise the position and make a concerted effort to find native born workers with the required skills. Only if they are unable to fill those positions with native born Americans are they allowed to obtain visas for foreign workers with the required skills.

Right now, the United States has 6.6 million job openings and a 3.9 percent national unemployment rate.[4] In technical fields, there are serious shortages in U.S.-based workers with science, technology, engineering, and math skills. America is not producing an adequate number of graduates in these areas and many top firms have employment numbers documenting this poor supply. Using the H1-B visa program to fill these positions is a reasonable way to tap the creativity of foreigners while still protecting American workers.

Likely Effects of Noncompete Agreements in High-Tech Sector

In the hearing, Representative Maloney asked about the likely effect of noncompete agreements in the high-tech sector. My view is that broadly-construed noncompete agreements are detrimental to innovation. They limit employee mobility and make it difficult for workers to launch the startups that are so vital to innovation, job creation, and American prosperity.

Right now, America is experiencing a dangerous slowdown in the number of startups. The United States used to average between 500,000 and 600,000 startups each year, but this number

has dropped to around 450,000 over the past decade. Since small firms create many of the new jobs, this slowdown is risky for the long-term economy.

There are many reasons for this decline, but one contributing factor has been the proliferation of noncompete agreements. Companies are deploying these contracts in order to limit the mobility of knowledge workers and the potential loss of intellectual property protections when an employee shifts to a new company. The fear is that mobile employees will provide special knowledge to new firms when he or she moves to another company.

Rather than employ across-the-board noncompete clauses for employment as a whole, a better way to handle this problem is to limit the disclosure of proprietary knowledge to new employers. Employees who share proprietary knowledge with new firms should be penalized in accordance with the value of the information they share. That would help protect company intellectual property while still allowing employees to be mobile in their job choices.

A secondary benefit of this approach would be to encourage more startups. Noncompete restrictions make it difficult for employees of large firms to leave and start their own companies. Limiting the usage of these agreements would help the startup economy and potentially lead to the formation of more small businesses. That would benefit the overall economy.

Endnotes

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[1] Alexander Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John Van Reenen, "Who Becomes an Investor in America? The Importance of Exposure to Innovation," National Bureau of Economic Research Working Paper 24062, November, 2017.

[2] Alexander Bell, Raj Chetty, Xavier Jaravel, Neviana Petkova, and John Van Reenen, "Who Becomes an Investor in America? The Importance of Exposure to Innovation," National Bureau of Economic Research Working Paper 24062, November, 2017.

[3] Thomas Piketty and Emmanuel Saez, "Income Inequality in the United States, 1913-1998" *Quarterly Journal of Economics*, Vol. 118, 2003, pp. 1-39. For 1999 to 2012 numbers, see the web page of Emmanuel Saez at http://emlab.berkeley.edu/users/saez.

[4] Heather Long, "The U.S. Now Has a Record 6.6 Million Job Openings," *Washington Post*, May 8, 2018.