SUPPORTING INNOVATION IN THE 21ST CENTURY ECONOMY

HEARING

BEFORE THE

SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

MARCH 24, 2010

Serial No. 111–90

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE
55–847PDF WASHINGTON : 2010

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2104 Mail: Stop IDCC, Washington, DC 20402–0001

COMMITTEE ON SCIENCE AND TECHNOLOGY

HON. BART GORDON, Tennessee, *Chair*

JERRY F. COSTELLO, Illinois
EDDIE BERNICE JOHNSON, Texas
LYNN C. WOOLSEY, California
DAVID WU, Oregon
BRIAN BAIRD, Washington
BRAD MILLER, North Carolina
DANIEL LIPINSKI, Illinois
GABRIELLE GIFFORDS, Arizona
DONNA F. EDWARDS, Maryland
MARCIA L. FUDGE, Ohio
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
JOHN GARAMENDI, California
STEVEN R. ROTHMAN, New Jersey
JIM MATHESON, Utah
LINCOLN DAVIS, Tennessee
BEN CHANDLER, Kentucky
RUSS CARNAHAN, Missouri
BARON P. HILL, Indiana
HARRY E. MITCHELL, Arizona
CHARLES A. WILSON, Ohio
KATHLEEN DAHLKEMPER, Pennsylvania
ALAN GRAYSON, Florida
SUZANNE M. KOSMAS, Florida
GARY C. PETERS, Michigan
VACANCY

RALPH M. HALL, Texas
F. JAMES SENSENBRENNER JR., Wisconsin
LAMAR S. SMITH, Texas
DANA ROHRABACHER, California
ROSCOE G. BARTLETT, Maryland
VERNON J. EHLERS, Michigan
FRANK D. LUCAS, Oklahoma
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
RANDY NEUGEBAUER, Texas
BOB INGLIS, South Carolina
MICHAEL T. MCCAUL, Texas
MARIO DIAZ–BALART, Florida
BRIAN P. BILBRAY, California
ADRIAN SMITH, Nebraska
PAUL C. BROUN, Georgia
PETE OLSON, Texas

SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION

HON. DAVID WU, Oregon, *Chair*

DONNA F. EDWARDS, Maryland
BEN R. LUJÁN, New Mexico
PAUL D. TONKO, New York
DANIEL LIPINSKI, Illinois
HARRY E. MITCHELL, Arizona
GARY C. PETERS, Michigan
BART GORDON, Tennessee

ADRIAN SMITH, Nebraska
JUDY BIGGERT, Illinois
W. TODD AKIN, Missouri
PAUL C. BROUN, Georgia

RALPH M. HALL, Texas

MIKE QUEAR *Subcommittee Staff Director*
MEGHAN HOUSEWRIGHT *Democratic Professional Staff Member*
TRAVIS HITE *Democratic Professional Staff Member*
HOLLY LOGUE *Democratic Professional Staff Member*
DAN BYERS *Republican Professional Staff Member*
VICTORIA JOHNSTON *Research Assistant*

CONTENTS

March 24, 2010

	Page
Hearing Charter	2

Opening Statements

Statement by Representative David Wu, Chairman, Subcommittee on Technology and Innovation, Committee on Science and Technology, U.S. House of Representatives	6
Written Statement	6
Statement by Representative Judy Biggert, Member, Subcommittee on Technology and Innovation, Committee on Science and Technology, U.S. House of Representatives	7
Written Statement	7

Witnesses:

Hon. Aneesh Chopra, Chief Technology Officer of the United States, White House Office of Science and Technology Policy (OSTP)	
Oral Statement	8
Written Statement	10
Biography	14
Dr. Mark Kamlet, Provost, Carnegie Mellon University	
Oral Statement	15
Written Statement	17
Biography	21
Dr. Robert D. Atkinson, President, the Information Technology and Innovation Foundation (ITIF)	
Oral Statement	21
Written Statement	23
Biography	54
Dr. Dan Breznitz, Associate Professor, the Sam Nunn School of International Affairs, Georgia Institute of Technology	
Oral Statement	55
Written Statement	57
Biography	63
Mr. Paul Holland, General Partner, Foundation Capital	
Oral Statement	64
Written Statement	66
Biography	72

SUPPORTING INNOVATION IN THE 21ST CENTURY ECONOMY

WEDNESDAY, MARCH 24, 2010

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
Washington, DC.

The Subcommittee met, pursuant to call, at 10:39 a.m., in Room 2318 of the Rayburn House Office Building, Hon. David Wu [Chairman of the Subcommittee] presiding.

HEARING CHARTER

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON TECHNOLOGY AND INNOVATION

Supporting Innovation in the 21st Century Economy

WEDNESDAY, MARCH 24, 2010
10:30 A.M.—12:30 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

Innovation, "the development of new products, services, and process,"[1] has had an indelible impact on the lives of Americans and is increasingly important for ensuring the well-being of the Nation's economy. While new technology like the Internet dramatically changed society in a short period of time, such profound innovation has remained elusive in sectors like energy, where fossil fuels have dominated for over a century. This hearing will examine factors that drive innovation, as well as those that impeded it. In addition, this hearing will discuss the role of the Federal Government in promoting the innovation that is crucial for American prosperity.

2. Witnesses

- **The Honorable Aneesh Chopra** is the Chief Technology Officer of the United States at the White House Office of Science and Technology Policy.
- **Dr. Mark Kamlet** is the Provost at Carnegie Mellon University.
- **Dr. Rob Atkinson** is the President of the Information Technology and Innovation Foundation.
- **Dr. Dan Breznitz** is an Associate Professor at the Sam Nunn School of International Affairs at Georgia Institute of Technology.
- **Mr. Paul Holland** is a General Partner at Foundation Capital.

3. Background

First developed in the late nineteenth century, the telephone became one of the most important inventions in the twentieth century. The technology, made possible by previous research in sound and electricity, created a new industry and new infrastructure, and greatly enhanced productivity across the entire economy. However, it is notoriously difficult to predict the impact of technological advances on society and the U.S. economy. For instance, in 1983 prominent experts forecasted that the demand for mobile phones in the U.S. would total only one million by 1999. Instead, by that time, 70 million Americans had cell phones. Rapid improvements in technology and reductions in costs made the original predictions obsolete.[2] In contrast, a Massachusetts company started in 1998 with promising technology to revolutionize skin grafts suffered bankruptcy and near-collapse before solving the manufacturing and logistical problems that allowed it to finally succeed a decade later.[3]

Regardless of the difficulty of predicting or creating it, economists have long studied the impact of innovation on the U.S. economy. Nobel Prize winner Robert Solow found that approximately 85 percent of the growth in the U.S. economy from the late nineteenth century to the mid-twentieth century was the result of forces beyond the traditional economic inputs of labor and capital. These "intangible" inputs—namely R&D and a more educated workforce—grew in importance in the twentieth century as innovations moved away from physical-capital intensive technology ad-

[1] *A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality* Jobs, Executive Office of the President, National Economic Council, and the Office of Science and Technology Policy. September, 2009.
[2] *Innovation and Economic Growth,* Nathan Rosenberg, Organization of Economic Cooperation and Development, 2004.
[3] *Innovation Interrupted,* BUSINESSWEEK, June 15, 2009.

vancements, like railroads, to more research-intensive advancements, like DNA sequencing.[4]

The increasingly competitive nature of the global economy has raised concerns among U.S. policy-makers and others that the U.S. has not sufficiently invested in maintaining leadership for the intangible inputs that drive innovation. The influential 2007 National Academies *Rising Above the Gathering Storm* report took note of factors such as declining Federal investment in R&D, poor performance in math and science among American schoolchildren, and declining support for corporate R&D within the U.S. The authors recommended increasing support for science and engineering research and targeted action to improve American students' capacity and interest in science, math, and related fields. Congress acted upon the recommendations with the *America COMPETES Act*, which put the budgets of the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST), and the Department of Energy Office (DOE) of Science on the path to doubling, and also provided for improvement in science and math education through teacher development.

President Obama's FY 2011 budget request includes $147.7 billion for R&D across the Federal Government, and reflects the commitments made in COMPETES by increasing the budgets of NSF (by eight percent), NIST (by 7.7 percent, core scientific and technical research services), and the DOE Office of Science (by 4.6 percent).[5] In addition to increasing R&D expenditures (with the goal of reaching a total R&D investment of three percent of GDP as a nation), the Administration has identified a number of other priorities which are key to supporting innovation for economic growth and job creation, such as broadband coverage, strong protection for intellectual property, better support of entrepreneurs, and increased effort to open-up foreign markets to U.S. exports.[6]

A number of Federal R&D programs use the word "innovation" within their titles or mission statements. For example, NSF spent nearly $50 million in FY 2009 on Industrial Innovation and Partnership funding and the Emerging Frontiers in Research and Innovation program (with an additional $19 million for ARRA (P.L. 111–5) funding). These programs fund a wide range of activities from research to making more efficient use of radio frequencies to developing measurements for sustainable construction practices and the development of applied mathematical models for complex engineered systems. The Department of Energy also makes a number of awards for innovation, such as the Energy Innovation Hubs to fund research to bridge the gap between basic scientific breakthrough and industrial commercialization. However, the authors of *Boosting Productivity, Innovation, and Growth Through a National Innovation Foundation*[7] note that while the Federal Government invests billions in R&D, there is very little funding directed toward "firm-level" innovation. They identified only two programs that focused directly on stimulating commercial innovation, NIST's Manufacturing Extension Partnership Program and its Technology Innovation Program. Other Federal programs, like the Defense Advanced Research Project Agency (DARPA) and the Small Business Innovation Research (SBIR) program focus on spurring technological development, but generally to accomplish a mission-related goal.

The authors of the *Boosting Productivity* report recommend that the Federal Government take a more active role in supporting innovation to help overcome some of the barriers faced by the private sector. These barriers, or market failures that disadvantage innovation, include the pressure to shift corporate R&D away from long-term breakthroughs, towards short-term development projects and the difficulties faced in aligning the needs of universities and the private sector to enable effective collaboration. The authors propose creating a National Innovation Foundation to remedy the shortcomings in Federal innovation policy, which they view as ad-hoc, too focused at the Federal-level, and too narrow (e.g., very little Federal science and technology support directly for the service-sector). This Foundation, an independent Federal agency, would fund industry-university research partnerships, make state-level grants to help promote regional industry clusters and technology commercialization, assist small firms in adopting new technologies, and support innovation throughout the Federal Government.

---

[4] *The Search for the Sources of Growth: Areas of Ignorance, Old and New,* Moses Abramovitz, The Journal of Economic History, June 1993.

[5] *Federal Research and Development Funding: FY 2011,* Congressional Research Service, March 2010.

[6] Executive Office of the President, National Economic Council, and the Office of Science and Technology Policy. September, 2009.

[7] *Boosting Productivity, Innovation, and Growth Through a National Innovation Foundation,* ITIF & Brookings, April 2008.

Investment in innovation is not confined to the Federal level. Many states, recognizing that they now must compete globally, as well as with each other, are making investments to improve the innovation capacity of their economies. Collectively, states spend approximately $1.9 billion per year on technology-based economic development activity.[8]

These types of initiatives, like the Oregon Nanoscience and Microtechnologies Institute, provide funds, facilities, and other services to high-tech start-up companies. Some states are also investing directly in R&D and in recruiting top science and engineering talent, such as Maryland's $23 million per year investment in stem cell research and Kentucky's decade long $350 million investment in recruiting top faculty to its universities.[9] States make many of these investments not only to improve their economies over a range of sectors, but also in an effort to spur the development of specific-industry clusters. The rise of Silicon Valley demonstrates the powerful force of cluster development both to regional economic growth and to spurring innovation. The Council on Competitiveness has identified clusters as a critical element to advancing regional competitiveness and innovation capacity. The presence of related industries, though, is only one piece of a strong innovative economy. A multitude of factors, such as workforce, R&D capacity, demand conditions, availability of capital, and local governance all affect the innovation capacity of regional economies.[10]

A study of Rochester, New York, by the Council on Competitiveness, illustrates the need for all of these factors to enable innovation. The study found that Rochester had the fundamental building blocks for an innovation economy, but lacked both the capital and culture to take the necessary risks to innovate. The area, dominated by Eastman Kodak and Xerox, has two well-regarded universities, a strong K–12 educational system, a skilled workforce, and a good transportation and communications infrastructure. However, despite the fact that workers there produce six-times the average number of patents as workers elsewhere in the country, the area ranked very low in terms of licensing technology and launching start-ups or spin-out companies. The authors attributed the low rate of entrepreneurship to the fact that the area had long relied on a few strong corporate entities, contributing to a risk-averse culture. In fact, between 1995 and 2003, the area attracted only 0.6 percent of the total venture capital market. The venture capital in the region tends to focus on the least risky opportunities. The report did note that the region is attempting to create coalitions around strengths like optics, and promote more collaboration between business and the universities.[11]

Funding to bring new discoveries from the lab into commercialization is critical for innovation. Experts have noted the declining level of funding available for early stage commercialization—the money needed for proof of concept or prototype development. Angel investors, independent investors working with their own funds, have traditionally focused funding at this early stage, but their contributions have dropped dramatically, particularly with the recent economic downturn ($19 billion in 2008, down from a five-year high of $26 billion in 2007). At the same time, venture capital investment is increasingly trending toward later stage investment. The NSF *Science and Engineering Indicators* reported that venture capitalists have largely abandoned seed and start-up stage funding from a high of nine percent in 1996 through 1998, to a low of two percent from 2002 to 2004. Currently, such funding stands at five percent, but this lack of early stage funding contributes significantly to the "valley of death phenomena" which makes commercialization of new technology notoriously difficult.[12]

Despite the increasingly competitive global environment, the U.S. is still a leader in knowledge and high-tech industries. According to the most recent National *Science Foundation Science and Engineering Indicators,* the U.S. provided 34 percent of knowledge intensive service industries (business, financial, and communications) in 2007 and 30 percent of the global value added for high technology manufacturing was accounted for by the U.S. However, the U.S. trade deficit in high-tech goods in 2008 was $80 billion.[13]

---

[8] *Boosting Productivity, Innovation, and Growth Through a National Innovation Foundation,* ITIF & Brookings, April 2008.

[9] *Innovation America: Investing in Innovation, National Governors Association,* The Pew Center on the States, 2007.

[10] *Clusters of Innovation Initiative: Atlanta-Columbus,* U.S. Council on Competitiveness

[11] *Fanning the Flames of Economic Progress: Igniting Greater Rochester's Entrepreneurial Economy,* U.S. Council on Competitiveness, September 2004.

[12] National Science Foundation *Science and Engineering Indicators,* 2010

[13] National Science Foundation *Science and Engineering Indicators,* 2010

4. Overarching Questions

- **What factors have enabled innovation in the past?**
- **What is the role of the Federal Government in spurring innovation?**
- **How can government best support entrepreneurs?**
- **What factors enable regional innovation-based economic growth? How can these be encouraged and sustained?**
- **How should efforts to create innovation be measured or assessed?**

Chairman WU. The hearing will come to order.

Good morning, everyone. I would like to thank you all for being here, and also for helping us think about a very challenging topic and one that frequently doesn't get addressed as well as in our Nation's capital as sometimes it gets addressed elsewhere in the country. We tend to get tied up in the issues of the day and the issues of the moment rather than looking a long ways down the road and also looking carefully at our own history, and it is very instructive that economists like Solow and others attribute at least 50 percent of our economic growth, and in some instances up to 90 percent of our economic growth, in the last century or especially in the post-war era is attributable to innovation, to things other than immediate changes in labor inputs and other factors. It is absolutely crucial that we understand the past in order to set our policies properly today to have the future that we want for our country and the world.

I view this as the beginning of a very important conversation that we are going to have here in the science and technology community. I know that this is a discussion which many of you have been initiating elsewhere but I think that bringing this to the Congress and supporting the Administration's efforts in this arena is absolutely crucial.

So today we have a beginning of the conversation, and I look forward to holding probably several hearings on this topic and looking at what pieces of legislation we can initiate from this Subcommittee and from the Full Committee to better encourage the innovative forces which have always been quite strong in our society and our economy but which sometimes suffer from some impediments and it is our task both to remove those impediments and also to engage in those activities which truly promote innovation and all the things that we want from innovation.

Chairman WU. With that, I would like to recognize Ms. Biggert, the gentlelady from Illinois, for her opening statement.

[The prepared statement of Chairman Wu follows:]

PREPARED STATEMENT OF CHAIRMAN DAVID WU

Good morning. I would like to thank everybody for being at today's hearing, particularly our witnesses.

Near the end of every year, *Time Magazine* publishes a list of that year's best inventions. Some on the 2009 list include rubber from dandelions, a 3–D camera, and highly maneuverable underwater robots. At one point, no doubt *Time's* list would have included the telephone, the transistor, or the polio vaccine. It is a challenging exercise in imagination to look at lists like these and try to predict which discovery will have the same level of impact as the Internet or the combustion engine, which discovery will go nowhere, and which will be tomorrow's airship—useful for a time, but made obsolete by superior technology.

It is not an exercise in imagination to contemplate the impact innovation has had on our economy and our lives. Economists estimate that innovation has been responsible for 50 to 85 percent of the economic growth in this country. The importance of innovation—creating new ideas, products, and services—cannot be overstated. And in this global, highly competitive economy, it is increasingly the intangible inputs of R&D, education, and entrepreneurial risk-taking that drive that growth. Innovation is key to creating new industries, and therefore key to the creation of American jobs.

As I'm sure the witnesses will tell us today, the government's commitment to funding research and education has had a major impact on fueling innovation. Innovation, though, is not just about expanding knowledge and making discoveries. Innovation brings new products and services into the marketplace that can then drive economic growth and future prosperity.

I hope the panel today can give us greater insight into the factors that have promoted innovation in the past and a picture of the health of our current innovation environment. I look forward to learning how the government can best support innovation. This is an important discussion to have as we look forward to reauthorizing America COMPETES.

Ms. BIGGERT. Thank you, Mr. Chairman, and thank you so much for calling this hearing on supporting innovation in the 21st century economy. As we move forward reauthorizing the *America COMPETES Act*, we can always learn from new ideas, from listening to a broad range of viewpoints, so I welcome that opportunity today.

And likewise, the President should be applauded for taking a committed interest in innovation as he has demonstrated with his strategy for American innovation, and we welcome you, Mr. Chopra, to this side of the Capitol.

But Chairman Wu, I think you will agree with me that innovation and competitiveness have long been at the forefront of this Committee agenda for as long as we have been members. I think we struggle to get some of our other members to be as engaged as we are, and I think you are right that in the hinterland there is probably a lot more emphasis on this. But we do understand its importance and we will continue to work towards ensuring that the United States remains the world's leader in innovation, and it is not only imperative to maintain our competitive edge but also to strengthen our economy.

And we took some major steps to reinforce our innovative future with the 2007 *America COMPETES Act*, which was a result of recommendations from the *Rising Above the Gathering Storm* Report, and I think that is where we really took that on, the previous Administration's American Competitiveness Initiative and the bipartisan leadership of this Committee, so as the chairman and I have both already mentioned, this hearing is a part of that reauthorizing process.

We are still waiting to see the benefits of some of the initiatives put into place in COMPETES as well as the return on investment from the more than $10 billion dollars in stimulus funding for R&D within this Committee's jurisdiction, so I hope that given our current economic climate, we proceed very cautiously with any new initiatives to spur innovation until we know our current investments are worthwhile.

So I want to thank our witnesses for being here today and I look forward to your testimony, and I yield back the balance of my time.

[The prepared statement of Ms. Biggert follows:]

PREPARED STATEMENT OF REPRESENTATIVE JUDY BIGGERT

Thank you, Mr. Chairman, for calling this hearing on supporting innovation in the 21st century economy. As we move forward on reauthorizing the *America COMPETES Act*, we can always learn new ideas from listening to a broad range of viewpoints, so I welcome that opportunity today.

Likewise, the President should be applauded for taking a committed interest in innovation as he has demonstrated with his *Strategy for American Innovation,* and we welcome you, Mr. Chopra, to this side of the Capitol. However, I am sure you will agree with me, Chairman Wu, that innovation and competitiveness have been at the forefront of this Committee's agenda for as long as we have been Members. We understand its importance and will continue to work towards ensuring that the United States remains the world leader in innovation. It is not only imperative to maintaining our competitive edge, but also to strengthening our economy.

We took some major steps to reinforce up our innovative future with the *2007 America COMPETES Act*, which was a result of recommendations from the *Rising Above the Gathering Storm Report*, the previous Administration's *American Competitiveness Initiative,* and the bipartisan leadership of this Committee. As the Chairman and I have both already mentioned, this hearing is part of that reauthorization process.

We are still waiting to see the benefits of some of the initiatives put into place in *COMPETES,* as well as the return on investment from the more than $10 billion in stimulus funding for R&D within this Committee's jurisdiction. I hope that, given our current economic climate, we proceed very cautiously with any new initiatives to spur innovation until we know our current investments are worthwhile.

I would like to thank our witnesses for being here today, and I look forward to your testimony. I yield back the balance of my time.

Chairman WU. Thank you very much, Mrs. Biggert.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Now it is my distinct pleasure to introduce our witnesses. Mr. Aneesh Chopra is the Chief Technology Officer of the United States at the White House Office of Science and Technology Policy. Welcome. It is absolutely wonderful to have an Administration which seems to really get it in terms of technology and innovation. Dr. Mark Kamlet, who is the Provost at Carnegie Mellon University. Dr. Rob Atkinson is the President of the Information Technology and Innovation Foundation. Dr. Dan Breznitz is Associate Professor at the Sam Nunn School of International Affairs at the Georgia Institute of Technology, and our final witness is Mr. Paul Holland, who is General Partner at Foundation Capital.

Welcome, one and all. You will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and I commend this to all of us as audience and witnesses, the body of work in the written testimony is truly impressive for its completeness and hitting on so many of the issues important to innovation. Each Member will have five minutes to question the panel after the spoken testimony, and Mr. Chopra, please begin.

STATEMENT OF HON. ANEESH CHOPRA, CHIEF TECHNOLOGY OFFICER OF THE UNITED STATES, WHITE HOUSE OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP)

Hon. CHOPRA. Well, thank you very much, Chairman Wu and Congresswoman Biggert. It is a pleasure to be with you and others here on the Subcommittee.

It is my honor and privilege to discuss the President's strategy for American innovation, an issue he addressed directly on September 21, 2009, when he released his approach for sustainable growth and quality jobs. As Chief Technology Officer, I work to execute on that strategy by harnessing technology, data and innovation to transform the Nation's economy and to improve the lives of everyday Americans. As you noted, I will briefly summarize the key highlights of my testimony for us this morning, beginning with what we define as the nature of the problem, which we call the problems of bubble-driven growth of the past. So despite America's economic strength historically, our economic growth has rested too long on what we believe to be an unstable foundation. Time and again, explosive growth in one sector of our economy provided a

short-term boost while masking what we consider to be some long-term weaknesses. A short-term approach to the economy masks the underinvestments in essential drivers of sustainable, broadly shared growth. It promotes temporary fixes over lasting solutions. That said, the American economy remains the most dynamic, innovative and resilient in the world. America's strengths are clear: world-class research universities, flexible labor markets, deep capital markets, and an energetic entrepreneurial culture. The United States must redouble its efforts to give our world-leading innovators every single chance to succeed. America cannot rest on our laurels while other countries are clearly catching up.

So the need for innovation is clear. It is the foundation for durable, sustainable expansion in both employment and economic growth. From our perspective, it begins with the development of a new product, service, or process. It then proceeds with widespread diffusion throughout our economy and at an appropriate scale, resulting in jobs and economic value.

So what is the proper role for government? The Obama Administration proposes to strike a balance by investing in the building blocks that only the government can provide, setting an open and competitive environment for business and individuals to experiment and grow, and by providing extra catalysts to jump-start innovation in sectors of national importance. I'd like to highlight just a few of those components, the building blocks of innovation. We are committed to making investments that will foster long-term economic growth and productivity including R&D, a skilled workforce, a leading physical infrastructure and widely available broadband networks. Given last week's Federal Communication Commission's release of the National Broadband Plan, I thought I would simply note we have established a broadband subcommittee within the National Science and Technology Council to advise this Administration on the actions it should take to promote broadband as a platform to improve the lives of everyday Americans and drive innovation in the economy.

On the topic of promoting competitive markets that spur productive entrepreneurship, here too we believe that this is a key imperative to create a national environment that is ripe for entrepreneurship. Part of this strategy is to change the way Washington works by promoting a more open and innovative government. Yesterday I was pleased to announce that the Defense Advanced Research Projects Agency, DARPA, will begin providing data on awardees in the Small Business Innovation Research Program that utilize a streamlined process for contracting and will extend this streamlined process to future SBIR solicitations starting with their one coming out on April 21st. Initially, DARPA will display data on the number of awardees that are eligible for this streamlined program, how many awardees have opted for it and the average number of days it took to complete.

Now, what does this mean? Typically, contracting can take up to five or six months to complete after you have been given an award. But we believe this streamlined approach will take on average less than 60 days. That represents a 60 to 70 percent reduction in both time and cost, saving small businesses tens of thousands of dollars and letting them get to work months faster.

Finally, on the topic of catalyzing breakthroughs for national priorities, we are absolutely committed to harnessing the power of science, technology and innovation to address our challenges in clean energy, health care and, broadly speaking, the grand challenges of the 21st century. Increasingly, our efforts to spur innovation on these matters rely on an effective, open and strategic collaboration between the Federal agencies and the private sector to ensure that the technological innovation needed to tackle these national problems is an opportunity for economic growth and job creation.

To that end, I am pleased to announce today that I am joining our Federal CIO [Chief Information Officer], Vivek Kundra, and OIRA [Office of Information and Regulatory Affairs] Administrator, Cass Sunstein, in establishing a new subcommittee on standards under the National Science and Technology Council's Committee on Technology, which will be co-chaired by Patrick Gallagher at NIST [National Institute of Standards and Technology] as well as Phil Wiser from the Department of Justice. This interagency group will provide high-level leadership so that Federal agencies are strategically focused and actively engaged in critical standards-related issues. The improved coordination will in turn ensure that agencies can work in a responsive and timely fashion with the private sector so that effective standards are developed or practiced to meet their needs. This subcommittee will work closely with the existing Interagency Committee on Standards Policy [ICSP], which also happens to be chaired by NIST. The subcommittee we announce today will provide direction and guidance to the ICSP and rely on them to fulfill their traditional duties and coordinating assessing progress and so forth.

In conclusion, Mr. Chairman, the United States is still the land of the future. We retain this honor because America's scientists, entrepreneurs and public officials have understood the importance of applying the power of American curiosity and ingenuity to the biggest economic and societal challenges. Clearly, we welcome any questions you may have.

[The prepared statement of Hon. Chopra follows:]

PREPARED STATEMENT OF ANEESH CHOPRA

Chairman Wu, Ranking Member Smith, and Members of the Subcommittee, it is my distinct privilege to be here with you today to discuss the Obama Administration's Strategy for American Innovation.

President Obama understands the importance of innovation for sustainable growth and quality jobs. On September 21st, 2009, he released his *Strategy for American Innovation* that identified three critical roles for the Federal Government: to invest in the building blocks of innovation; to create the right environment for private sector investment and competitive markets by, for example, promoting high-growth entrepreneurship, protecting U.S. intellectual property rights, and fostering an open government; and to serve as a catalyst for breakthroughs related to national priorities such as clean energy, health care, and other "grand challenges" of the 21st century.

In my capacity as Assistant to the President, Chief Technology Officer, and Associate Director for Technology in the Office of Science and Technology Policy, my mission is to harness the power and potential of technology, data, and innovation to transform the Nation's economy and to improve the lives of everyday Americans. The Administration envisions an economy in which jobs are more plentiful, American firms are more competitive, Americans are safer and more secure, and energy use is cleaner and more economical.

Problems with the Bubble-Driven Growth of the Past

Despite the American economy's historic strength, our economic growth has rested for too long on an unstable foundation. Time and again, explosive growth in one sector of our economy provided a short-term boost while masking long-term weaknesses. In the 1990s, the technology sector climbed to unprecedented heights of valuation. The tech-heavy NASDAQ composite index rose over 650 percent between 1995 and 2000, but then lost two-thirds of its value in a single year.

After the tech bubble burst, a new one emerged in the housing and financial sectors. This type of growth isn't just problematic when the bubble bursts, it is not entirely healthy even while it lasts. Between 2000 and 2007 the typical working-age American household saw its annual income decline by nearly $2,000.

A short-term approach to the economy masks under-investments in essential drivers of sustainable, broadly-shared growth. It promotes temporary fixes over lasting solutions. This is patently clear when looking at how American education, infrastructure, healthcare, energy, and research—all pillars of lasting prosperity—were ignored during the last bubble.

Despite this underinvestment in key drivers of growth, the American economy remains the most dynamic, innovative, and resilient in the world. America's strengths are clear: world-class research universities, flexible labor markets, deep capital markets, and an energetic entrepreneurial culture. The United States must redouble its efforts to give our world-leading innovators every chance to succeed. America cannot rest on our laurels while other countries are catching up.

The Need for Innovation

Innovation is at the core of a new foundation for durable, sustainable expansion in both employment and economic growth. Robert Solow won the Nobel Prize in economics by showing that factors other than capital intensity, most notably advances in human knowledge and technology, accounted for almost 90 percent of the growth in America's output per hour in the first half of the last century. Growth accounting has been refined since Solow's first attempts, yet contemporary research still shows that human skill and innovation remain far and away the most powerful force for improving prosperity over the long-run, which is exactly what we need.

Given its importance, the process of innovation cannot be taken for granted. It begins with the *development* of a new product, service or process. But it does not end there. To create value, a new idea must be implemented. Thus successful innovations will *diffuse* throughout an economy and across the world, impacting various sectors and sometimes even creating new ones. A diffused innovation must then *scale* appropriately, reaching an efficient size at which it can have a maximal effect.

The full process—from development to diffusion to scaling—has many variables and many inputs. Ideas often fail before they make it through the full chain. But those that do succeed can create value and jobs while improving people's lives.

It is essential for the long-run prosperity of our society that innovations flourish and progress along this chain. And here, government has a fundamental role to play.

The Appropriate Role for Government

While it is clear that a new foundation for innovation and growth is needed, the appropriate framework for government involvement is still debated. Some claim that the laissez-faire policies of the last decade capture the right strategy, and that the recent crisis was the result of too much rather than too little government support. Another view is that the government must dominate certain sectors, protecting and insulating those areas thought to be drivers of future growth. The Obama Administration rejects both sides of this unproductive and anachronistic debate.

The United States proposes to strike a balance by investing in the building blocks that only the government can provide, setting an open and competitive environment for businesses and individuals to experiment and grow, and by providing extra catalysts to jumpstart innovation in sectors of national importance.

A Strategy for American Innovation

President Obama has already taken historic steps to lay the foundation for the innovation economy of the future. In the Recovery Act alone the President committed over $100 billion to support groundbreaking innovation with investments in energy, basic research, education and training, advanced vehicle technology, health IT and health research, high speed rail, smart grid, and information technology.

The Obama Innovation Strategy has three parts: investing in the building blocks of innovation, promoting competitive markets that spur productive entrepreneurship, and catalyzing breakthroughs for national priorities.

Investing in the building blocks of American innovation

President Obama is committed to making investments that will foster long-term economic growth and productivity. These investments are in areas that include research and development, a skilled workforce, a leading physical infrastructure, and widely available broadband networks.

Recognizing the need for long-term and sustained investments in R&D, President Obama has pledged to complete the doubling of funding for three key science agencies, the National Science Foundation, the laboratories of the National Institute of Standards and Technology, and the Department of Energy's Office of Science. In his landmark address before the National Academy of Sciences, President Obama set a goal of lifting the sum of public and private investment in R&D to three percent of GDP, which would exceed the level achieved at the height of the space race. As the President noted, "science is more essential for our prosperity, our security, our health, our environment and our quality of life than it has ever been before." To encourage private sector investment in R&D, the President has proposed making the Research and Experimentation Tax Credit permanent. The Obama Administration is working to increase the impact of this investment by providing greater support for university commercialization efforts, for high-risk, high-return research, for multidisciplinary research, and for scientists and engineers at the beginning of their careers. For example, the National Science Foundation's FY 2011 budget proposes to double support for the Partnerships for Innovation program, which will help universities move ideas from the lab to the marketplace.

The Obama Administration is committed to expanding access to broadband. Last week, the Federal Communications Commission (FCC) released the National Broadband Plan, called for in the American Recovery and Reinvestment Act, to identify ways to expand access to broadband and promote economic growth and job creation.

In his statement on the plan's release, the President committed to "build upon our efforts over the past year to make America's nationwide broadband infrastructure the world's most powerful platform for economic growth and prosperity." To that end, I've established a Broadband Subcommittee of the National Science and Technology Council's Committee on Technology, to focus closely on the plan that the FCC—an independent agency—produced, and to advise the Administration on the actions it should take to promote broadband as a platform to improve the lives of everyday Americans and drive innovation in the economy.

Promoting competitive markets that spur productive entrepreneurship

The Obama Administration believes that it is imperative to create a national environment that is ripe for entrepreneurship and risk taking, and allows U.S. firms to compete and win in the global marketplace. The Administration is pursuing policies that will promote U.S. exports, support open capital markets, encourage high-growth entrepreneurship, invest in regional innovation clusters, and improve our patent system. The Administration also strongly supports public sector and social innovation.

Competitive, high-performing regional economies are the building blocks for national growth, and the Administration is stepping up its efforts to cultivate regional economic clusters across the country. For example, the Administration has just announced a $130 million competition for an Energy Regional Innovation Cluster. This pilot project is designed to spur regional economic growth while developing energy efficient building technologies, designs, and systems. This will allow a region to develop a strategy that includes support for R&D, infrastructure, small and medium-sized enterprises, and workforce development.

Innovation must occur within all levels of society, including the government and civil society. The Obama Administration is committed to increasing the ability of government to promote and harness innovation. The Administration is encouraging departments and agencies to experiment with new technologies that have the potential to increase efficiency and reduce expenditures, such as cloud computing. The Federal Government should take advantage of the expertise and insight of people both inside and outside the Federal Government; use high-risk, high-reward policy tools such as prizes and challenges to solve tough problems; support the broad adoption of community solutions that work; and form high-impact collaborations with researchers, the private sector, and civil society.

The Administration launched the White House Open Government Initiative to coordinate Open Government policy, support specific projects, and design technology platforms that foster transparency, participation and collaboration across the Executive Branch. The principles of open government help to advance a set of key national priorities with emphasis on demonstrating tangible benefits for the American people.

As an example, I am pleased to announce that the Defense Advanced Research Projects Agency (DARPA) will begin providing data on awardees in the Small Business Innovation Research (SBIR) program that utilize a streamlined process for contracting, and will extend this streamlined process to future SBIR solicitations. The SBIR program is one of the major Federal Government programs used to support innovative technologies in America—yet the paperwork is cumbersome, lengthy and time consuming. These new steps represent a significant improvement—think of this as the 1040 EZ for Federal Government innovation grants. Initially, DARPA will display data on the number of awardees that are eligible for this streamlined process, how many awardees opted to utilize this process, and the average number of days it took to complete the streamlined agreement. In addition, the next round of DARPA's SBIR solicitations, scheduled for April 21st, will for the first time announce the wide availability of this streamlined option.

Typically contracting would take from five to six months to complete, but we believe that the streamlined approach will take on average less than 60 days. This represents a 60 to 70% reduction in the time and cost, saving small businesses tens of thousands of dollars and letting them get to work months faster.

By taking these steps, the Federal Government is matching young, innovative companies responsible for creating new technologies, new jobs and America's future economic growth with Federal funding that meets their needs.

Catalyzing breakthroughs for national priorities

President Obama is committed to harnessing science, technology and innovation to unleash a clean energy revolution, improve America's health care system, and address the "grand challenges" of the 21st century.

Smart Grid Technologies

Modernization of the Nation's electric grid is a vital component of efforts to build a low-carbon economy. The "smart grid" will help provide consumers with the information, automation, and tools they need to control and optimize energy use. The tools and services enabled by the smart grid will improve the reliability, security, and efficiency of the electric grid. Smart grid technologies can facilitate energy generation from clean energy supplies and enable more effective integration with the electricity delivery system of renewable energy sources, demand response resources, and plug-in electric vehicles. The National Institute of Standards and Technology (NIST) has coordinated an unprecedented, open, and transparent public/private collaboration involving over 550 companies, organizations and government agencies to create the interoperability standards needed to foster innovation in the electric grid.

One month ago, in conjunction with NIST, we broadened participation by launching the Smart Grid Forum, an on-line forum focused on the Nation's energy consumers with an emphasis on spurring innovation in smart grid products and services. We received comments from over 130 individuals and organizations contributing their solutions to some of the most challenging smart grid goals that we have—from deployment of smart grid solutions, to development of standards needed for information exchange, to ensuring cybersecurity in the smart grid.

Healthcare IT

Another important Presidential priority is improving our health care system. Broad use of health information technology has the potential to improve health care quality, prevent medical errors, increase the efficiency of care provision and reduce unnecessary health care costs, reduce paperwork, increase administrative efficiencies, expand access to affordable care, and improve population health. The Recovery Act provides support for the deployment of health information technology, such as electronic health records. The Office of the National Coordinator for Health IT and the Centers for Medicare & Medicaid Services are working to ensure that health information technology products and systems are secure, can maintain data confidentially, can work with other systems to share information, and can perform a set of well-defined functions. NIST, in coordination with the Office of the National Coordinator and others, is accelerating the adoption of health IT standards by providing the critical testing infrastructure needed to achieve these goals.

One month ago, the Office of the National Coordinator for Health IT announced a new collaborative, *NHIN Direct,* which will organize a set of standards, services and policies that enable secure health information exchange over the Internet (*www.nhindirect.org*). Several Federal agencies and healthcare organizations are already using the Nationwide Health Information Network (NHIN) technology to exchange information amongst themselves and their partners. This new effort will provide an easy "on-ramp" for a wide set of providers and organizations looking to adopt the exchange of health information—and provide a framework to spur innovation in support of direct communication amongst providers, and between providers and patients—in a secure and simple manner.

Grand Challenges

Finally, the Obama Administration believes that grand challenges should be an important organizing principle for science, technology and innovation policy. They can address key national priorities, catalyze innovations that foster economic growth and quality jobs, spur the formation of multidisciplinary teams of researcher and multi-sector collaborators, bring new expertise to bear on important problems, strengthen the "social contract" between science and society, and inspire students to pursue careers in science, technology, engineering, and mathematics. The President's innovation strategy sets forth a number of grand challenges, such as solar cells as cheap as paint, educational software that is as compelling as the best video game and effective as a personal tutor, and early detection of diseases from a saliva sample. The National Economic Council and the Office of Science and Technology Policy are encouraging multi-sector collaborations to achieve these grand challenges that might involve companies, research universities, foundations, social enterprises, non-profits, and other stakeholders.

The Way Forward

Thanks to President Obama's leadership, the Administration has taken large strides in developing and implementing an ambitious innovation agenda. The Recovery Act alone provides over $100 billion to support research and development and the deployment of advanced technologies such as clean energy, health IT, the smart grid, and high-speed rail. This commitment to investing in America's future continues in the President's most recent budget, with sustained support for research, entrepreneurial small businesses, education reform, college completion, and a 21st century infrastructure.

The Administration is working with a wide range of stakeholders to identify the most promising ideas for implementing and further refining the Administration's innovation strategy. There are active inter-agency working groups on issues such as prizes and challenges, regional innovation clusters, research commercialization, spectrum reform, broadband, open government, and standards. The National Science and Technology Council is leading multi-agency research initiatives in dozens of critical areas such as aeronautics, genomics, green buildings, nanotechnology, quantum information science, robotics, and information technology. Through the President's Council of Advisors on Science and Technology, the Administration is able to receive high quality advice from the Nation's leading scientists, engineers and innovators on issues such as health information technology, advanced manufacturing, clean energy, and STEM education.

America has always been a Nation built on hope—hope that we can build a prosperous, healthy world for ourselves and for our children. These long-standing American aspirations depend critically on our far-sighted investments in science, technology and innovation that are the ultimate act of hope and will create the most important legacies we can leave.

The United States is still the land of the future. We have held that honor since this continent was discovered by a daring act of exploration more than 500 years ago. We have earned it anew with each passing generation because America's scientists, entrepreneurs and public officials have understood the importance of applying the power of American curiosity and ingenuity to the biggest economic and societal challenges.

I welcome any questions that the Committee may have.

BIOGRAPHY FOR ANEESH CHOPRA

Aneesh Chopra is the Chief Technology Officer and in this role serves as an Assistant to the President and Associate Director for Technology within the Office of Science & Technology Policy. He works to advance the President's technology agenda by fostering new ideas and encouraging government-wide coordination to help

the country meet its goals from job creation, to reducing health care costs, to protecting the homeland. He was sworn in on May 22nd, 2009. Prior to his appointment, he served as Secretary of Technology for the Commonwealth of Virginia from January 2006 until April 2009. He previously served as Managing Director with the Advisory Board Company, a publicly-traded healthcare think tank. Chopra was named to Government Technology magazine's Top 25 in their Doers, Dreamers, and Drivers issue in 2008. Aneesh Chopra received his B.A. from The Johns Hopkins University and his M.P.P. from Harvard's Kennedy School. He and his wife Rohini have two young children.

Chairman WU. Thank you very much, Mr. Chopra.

Dr. Kamlet, please proceed.

STATEMENT OF DR. MARK KAMLET, PROVOST, CARNEGIE MELLON UNIVERSITY

Dr. KAMLET. Chairman Wu, thank you very much, and it is an honor to be able to participate in this hearing.

As Provost and Executive Vice President of Carnegie Mellon, I am here today to offer perspectives on supporting innovation from the trenches, so to speak. I will cover two main areas in my brief remarks. First, I would like to offer a quick overview of Carnegie Mellon's experience in helping to shape a pathway from research to innovation, and second, based upon these experiences, I will offer a few thoughts for your consideration on Federal policies that can help ensure continued U.S. leadership in technology-based innovation in the future.

I should say that as with our peer institutions, we have benefited immeasurably from the strong historic partnership with the Federal Government that has made the American research university truly unique in the world as an engine for new business creation, and of course, this partnership was dramatically energized by the Bayh-Dole Act, which over the last 30 years has made technology transfer a critically important university mission. But Carnegie Mellon's experience highlights the importance, as well, of supporting the Federal investment in research with deliberative strategies that create a culture of innovation and speed research to the marketplace. At Carnegie Mellon, we have implemented two strategic thrusts to directly accelerate commercialization.

First, we overhauled our tech transfer process in 2004 to create a streamlined, transparent approach for faculty seeking to create new companies known as our "5% go in peace" policy, named such because of the fact that we cap university equity at five percent, up to $2 million dilution event, and that this strategy has largely removed the conflicts that often accompany negotiations over faculty startups. Combined with a series of supporting initiatives that range from widespread entrepreneurial education for faculty and students, to the placement of embedded entrepreneurs right in the heart of research labs, the 5% go in peace approach has more than doubled our rate of new business creation. We now have 10 to 20 new companies that we launch each year, and we rank consistently among the top three universities in the Nation in surveys by AUTM [Association of University Technology Managers] of university startups and first among universities without a medical school.

Our second major strategic thrust has been a campus-wide commitment to regional economic development born from a sense of our need to contribute to our region's recovery from the collapse of the

steel industry. That focus has included aggressive efforts to directly link faculty research to the attraction of companies to Pittsburgh. As a result of this focus on economic development, we have succeeded in helping bring companies such as Apple, Intel, Google, Disney and Caterpillar to Pittsburgh.

More critically, this economic development commitment has fostered a vibrant environment for the industry-university research collaboration as with the burst of new startups created by our 5% go in peace policy. The collaborations stemming from this focus on economic development have created new channels for commercializing university research.

Let me offer three key suggestions on what lessons the Carnegie Mellon experience may hold for policies that can support innovation. First, I believe that we can significantly improve the climate for innovation by focusing small but targeted Federal investments to fill the gap between the end of basic research and the point where private investments or even SBIR funding can support startup development or licensing. This gap often involves the development of pre-commercial prototypes and other early market tests. The Obama Administration has proposed $12 million in the innovation ecosystem funding in the NSF budget. This and ideas such as the notion of regional prototype centers offered by Secretary Locke will be valuable steps towards filling this gap. This funding should come with strings that hold universities accountable for creating the policies and environment necessary for commercialization to thrive.

Second, I believe there is great promise in seeking to identify niche areas for Federal science funding where greater synergy can be created between basic research and technology development to accelerate commercialization. For example, over the last two years, faculty from Carnegie Mellon have joined with colleagues at ten other universities and a range of industry leaders to create a roadmap for commercial robotics. This roadmap outlines a shared vision for advances in both fundamental research and shorter-term barriers to commercial application that must be addressed to dramatically expand the U.S. robotics industry.

Finally, we need to create the equivalent of a Bayh-Dole Act for university-industry collaboration, a broad framework that can reinvigorate partnership development. Two pillars to build this framework would include a lessening of restrictions that impede the ability of universities to conduct exclusive research for companies in buildings funded with tax-exempt bonds and more focused provisions for the industry-university collaboration in the R&D tax credit.

In closing, I want to thank the Members of this Committee for their commitment to preserving U.S. leadership in science and technology. I have witnessed the fruit of it directly in the research labs at Carnegie Mellon and we are grateful for your leadership. Thank you very much.

[The prepared statement of Dr. Kamlet follows:]

PREPARED STATEMENT OF MARK KAMLET

Introduction

Thank you Chairman Wu, Ranking Member Smith, and Members of the Committee for the opportunity to speak to you today and to share perspectives on strategies to maintain and reinvigorate the leadership of the United States in innovation-led job and business growth. My name is Mark Kamlet. I am the Provost and Executive Vice President of Carnegie Mellon University. I serve as the chief academic officer of CMU but I have also been very engaged in our tech transfer policies and directly involved in a number of university spin-out companies. I also serve on the National Academy of Sciences panel on intellectual property—though my remarks today reflect only my views and not those of the panel.

My comments will focus on two key areas. First, I will share briefly with you Carnegie Mellon's experience in seeking to create a culture that accelerates the path from basic research to commercialization. Second, my remarks will seek to discern lessons from these experiences that may be of value as you assess policy options to ensure that the U.S. remains the world leader in innovation and, particularly, the capacity for innovation to stimulate broad-based economic opportunity.

However, it is important that I first begin by thanking you and the members of this Committee for your tireless support of the advancement of science and technology. This Committee has been a steadfast proponent of policies to maintain U.S. science excellence and an "incubator" of the kinds of creative ideas needed to refresh and rejuvenate our leadership for a changing world. I have witnessed the impact of this leadership directly in labs within Carnegie Mellon and I am grateful for your efforts.

Recognizing Our Strengths: The Vitality of the American Research University Partnership

An effort to assess future directions for U.S. innovation policy must begin with recognition of the core vision and values that have been at the heart of our success to date. The fundamental partnership between the Federal Government and American higher education in the post-war period to create the modern research university has been the greatest catalyst to economic growth in the last half century. While the U.S. faces intense competition in the global economy it is worth noting that we possess one asset that no other nation has yet duplicated—the capacity of university based research to launch high growth companies. There is virtually no equivalent of "Google" emerging from dorm rooms in universities in Europe or Asia. This is an asset we must seek to nurture for the future.

The power of this partnership in creating the modern research university was in my view greatly enhanced by the passage of the Bayh-Dole Act. Bayh-Dole extended this partnership by fully engaging universities in technology transfer and spin-out development. At its essence, the Bayh-Dole Act created a vehicle for leveraging U.S. investment in basic research into a stronger engine for commercialization.

Bayh-Dole was enacted at a time when the U.S. economy faced economic challenges nearly as severe as those we currently confront. In 1980 the U.S. economy was beset by double digit unemployment and double digit inflation. The rise of international competition had brought the phrase "rust belt" into the popular lexicon for the first time. In Pittsburgh, America's epicenter of economic dislocation in the early 1980s, over 100,000 jobs were lost in the steel industry in less than three years.

The Bayh-Dole Act created the foundation for the innovation-led recovery of the 1980s and the growth of the 1990s. Since the enactment of Bayh-Dole the university community's commitment to technology transfer has skyrocketed. The number of university tech transfer programs increased from 30 to over 300. Over 5,000 new companies have been created and university-based patents and product introductions have also risen dramatically.

Without question I believe that the U.S. investment in science and basic research would never have produced the commercial and job dividends so vital over the last two decades without the Bayh-Dole Act and its impact on energizing universities to become partners and advocates for commercialization.

But while a recognition of those historic strengths is vital to charting a course forward, past achievements are no guarantee for a future where we face fundamental new challenges from increasing international competition, a critical need to overcome a period of stagnation in Federal support for basic research, some evidence of a plateauing in university-based patenting trends and unmistakable indications that the vital link between basic research and innovation-led job growth has weakened if not broken completely. I will seek to identify lessons from Carnegie Mellon's

experiences that may hold promise for writing a new chapter in the innovation compact between the Federal Government and American universities.

Searching for Strategies to Rejuvenate Innovation: Lessons from Carnegie Mellon's Experiences

Carnegie Mellon University brings perspectives on these challenges from a relatively unique history among leading American research universities. Created in 1900 to be a technical trade school for the sons and daughters of steelworkers, the University is the youngest Top 25 research institution in the U.S. Our roots have instilled a focus on practical problem solving and a culture of interdisciplinary research that have been critical to our capacity to stimulate innovation.

Nevertheless, we have faced the challenge of having to forge policies and a cultural environment capable of generating significant results. Upon becoming provost in 2000, I confronted the strong findings of a University committee convened to guide the search for my position that concluded that Carnegie Mellon's tech transfer process was broken. The Committee found that the policies and processes in place at that time instilled conflict between the University and our faculty and choked off both commercialization and start-up creation.

Our response was an overhaul of Carnegie Mellon's tech transfer process and the creation of what we call the "5% go in peace" approach. This approach creates a streamlined, common template for faculty based start-ups that limits university equity to 5% capped at a $2 million dilution event, establishes clear royalty guidelines with a three year delay in payments and ensures virtually no University interference in start-up operations. This streamlined template has been augmented by supportive policies that allow faculty to incubate companies in University labs for short periods and that also allow faculty to hold C-level positions in the companies they create.

The 5% go in peace program has also been bolstered by the establishment of a supportive innovation ecosystem across the University. This ecosystem consists of aggressive entrepreneurial training and outreach that engages over 10% of the student population each year. It also includes the strategic placement of entrepreneurs in residence in key areas to jump start the development of ideas for new companies. In addition, a new initiative in computer science, known as Project Olympus, is bringing focused assistance on entrepreneurship to researchers in the earliest phases of research. One Project Olympus supported start-up was recently acquired by Google. Finally, we augment our streamlined processes for start-up creation with intense collaboration with regional economic development organizations to ensure that our companies have fertile ground for growth after leaving the University.

The 5% go in peace approach has been a catalyst to innovation. The rate of university spin-outs has doubled since the implementation of this policy in 2004. Since 2007, Carnegie Mellon has ranked number #1 among all U.S. universities without a medical school in the number of start companies created per research dollar spent and ranked number two in the Nation among all universities in 2008 (source: AUTM, the Association of University Technology Managers).

On average the University creates 10 to 20 new companies each year. These start-ups range from robotics firms launching new applications for manufacturing and services, to video game companies, to a new battery storage company and a recent start-up that has developed a technology to utilize a person's blood to engineer plastics for plates to be used in medical procedures in order to reduce rejection rates. While most of these start-ups focus on leading edge technologies, nearly one-third involve the manufacturing of products. University-based innovation is capable of far reaching impacts.

This focus on creating an ecosystem to support start-ups has been mirrored by a University-wide commitment to economic development by Carnegie Mellon's President, Jared Cohon. This commitment has resulted in the creation of an on campus facility to ease the ability of companies to launch operations in Pittsburgh. The facility is currently home to Apple, Intel and Google. Carnegie Mellon has also helped to attract Caterpillar, Disney Research and Rand to Pittsburgh. Other major tech leaders such as Network Appliance, Foster Miller and Cadence Design Systems have entered the Pittsburgh market by purchasing CMU-related companies.

This focus on economic development has done more than simply contribute to the nearly 9,000 jobs created by Carnegie Mellon related companies in the Pittsburgh region that are central to the area's recovery from the collapse of the 1980s. A University wide commitment to economic development has helped to establish entirely new models for industry/university research collaboration—the second core component of the innovation equation. While each company tends to pursue its own unique model of collaboration ranging on a spectrum from open source research to

highly proprietary engagements, our experience demonstrates that a commitment to economic development is a vital catalyst to building the strong faculty/company relationships that are essential to stimulating innovation.

Challenges and Potential Strategies for the Road Ahead

The Carnegie Mellon experience demonstrates that a focus on accelerating start-ups and a commitment to regional economic development as a core university mission can help establish a culture of innovation that produces tangible commercialization outcomes. At the same time we confront clear challenges that illustrate the difficulties the Nation faces in accelerating innovation-led job growth.

These challenges fall into two major areas. First, at a time when universities and the Federal Government face enormous fiscal challenges, the resources needed to advance basic research outcomes to the point where a determination can be made as to whether they provide the basis for licensing or start-up creation are virtually non-existent.

The scale of resources required is not large. An investment of $100,000 in a promising area, for example, can often enable a researcher to make the leap from concept to commercial potential. But currently, universities must rely on either internal sources or foundations for these funds and the net result is a lower return on U.S. investment in basic research.

The Federal effort most applicable to meeting this gap is the SBIR program. However, the need for pre-commercial prototyping is often-greatest before a researcher would be ready to start a firm and be SBIR eligible.

The second challenge is the need to fundamentally reevaluate strategies to encourage stronger partnerships between universities and new industry. While Carnegie Mellon's focus on economic development has fostered important collaborations, the overall climate created by key tax policies is having a chilling effect on the capacity to stimulate a stronger research partnership with companies. I believe that this climate is hindering our capacity to link university research to capturing manufacturing opportunities in the U.S.

Recognizing these two main challenges I would offer the following three recommendations for consideration.

(1) **Create funding sources to close the gap between basic research and commercialization**

I would strongly encourage Committee consideration of experimental approaches to enhance investment in moving basic research outcomes closer to commercialization. The President has proposed one approach to fill this gap by including $12 million in the proposed FY 2011 NSF budget for Innovation Ecosystem grants. The goal of this proposal is to provide support for programs that link researchers to resources that can evaluate the potential for new business creation or commercial licensing earlier in the research process.

Secretary Locke has also discussed the potential creation of regional "prototype development centers" that would also facilitate pre-commercialization refinement of research activities. A national pilot program in efforts such as these could both test their effectiveness and foster the creative development of strategies.

This funding should come with clear requirements however to ensure a Federal return. I would propose for example that to be eligible, universities must demonstrate that they have in place policies conducive to start-ups and commercialization and have created the economic development partnerships vital to foster innovation. Where applicable these programs should also enhance collaboration among universities in the commercialization process.

(2) **Invest in Targeted Research Initiatives that have the Potential to Dynamically Link Fundamental Research and Commercialization**

The ability to stimulate innovation would also be enhanced by exploring opportunities to target investments towards areas where a strong synergy exists between advancements in basic research and near term commercial growth.

For example, over the last two years researchers at Carnegie Mellon have joined their colleagues at ten other universities and a number of major companies to develop a roadmap for the future of U.S. commercial robotics. Funded by the Computing Community Consortium, the roadmapping proc-

ess focused on identifying near term, medium range and long term application and research needs.

The outcome of this work is an integrated vision for linking continued progress in fundamental research areas vital to breakthrough advances with near term technology gaps that can accelerate new product innovations in manufacturing, health care, education and service applications. This approach harnesses the best strengths of U.S. research universities but creates a framework for collaborations on near term innovations that can stimulate new companies and technology transfer. I believe similar initiatives in areas such as the science of learning or the brain sciences where major breakthroughs in fundamental research have recently been made could also be fertile ground for this type of approach.

(3) **Establish a National Focus on Rejuvenating Industry-University Collaboration**

Just as the Bayh-Dole Act ushered in a boom in university based start-ups, the U.S. is in need of an overall strategy or policy framework for increasing collaboration among companies and universities. Such a framework should assess both current barriers and opportunities for new incentives.

One starting point for developing this framework would be an examination of the U.S. Tax code and Revenue Procedure 97–14 which places restrictions on the ability of universities to effectively engage companies. This procedure precludes companies sponsoring research projects from receiving preferential treatment in licensing. In effect, it requires universities to essentially stipulate that companies cannot own the IP coming from research they fund. It is a barrier unique to the U.S. and a major competitive disadvantage.

Efforts were made in Revenue Procedure 2007–47 to mitigate the impact of these provisions. But these changes still largely preclude the ability of companies to readily obtain exclusive licenses for research that they fund in buildings financed with tax exempt bonds.

Arguments can be made that altering these provisions would foster unfair competition with private sector research or undermine the basic mission of universities. I believe these issues can be addressed and that the competitive challenges facing the U.S. demand that we try.

A second starting point for this initiative would be to continue to explore modifications to the R & D tax credit that would incentivize university collaboration. At a time when companies are increasingly off-shoring research operations, tax incentives for university collaborations could be a valuable tool for retaining innovation capacity in the U.S.

Finally, an initiative to rejuvenate university/industry collaborations should focus specifically on opportunities to more closely link basic research to manufacturing. Carnegie Mellon is launching a campus-wide initiative called the Manufacturing Accelerator to create more direct pathways between leading edge basic engineering and computer science research and manufacturing.

The Accelerator will leverage a network of over 200 small and medium sized Pennsylvania firms to focus basic research on industry defined product and process opportunities. Any effort to stimulate stronger university/industry collaboration must include strategies for extending that partnership to production.

Conclusion

Thank you again for your commitment to American leadership in science and the opportunity to share Carnegie Mellon's experiences in seeking to ensure that the Federal investment in basic research stimulates innovation. The U.S. confronts the challenges from a unique position of strength. The American research university is an asset not yet matched anywhere in the world.

But the times demand that we evaluate strategies that can insure that this asset fosters broad-based economic opportunities in the future. Carnegie Mellon has worked to foster a culture of innovation that has accelerated new business creation and commercialization research partnerships with companies. Our experiences suggest that strategic policy initiatives could serve to reinvigorate the overall climate for university-based innovation.

These strategic initiatives should include new funding sources that bridge the gap between basic research and commercialization anchored in strict requirements for

universities to put in place and maintain start-up supportive policies. Second, focusing some segment of basic research funding on targeted areas where close collaboration to foster synergy between fundamental science breakthroughs and barriers to commercial applications, such as robotics, would be a critical step to accelerate research-based innovation. Finally, a broad-based effort to explore means of enhancing the environment for industry/university collaboration is clearly needed. A focus on tax code and tax credit actions as well as an assessment of opportunities that create closer linkages between university research and manufacturing activities could provide a starting point for establishing a policy framework as bold as the Bayh-Dole Act proved to be in launching an era of start-up creation.

In closing, let me pass on the observation that one cannot spend time on the campus of an American university without coming away with a renewed belief that our best times are ahead of us. Carnegie Mellon and the entire university community stand ready to join you in advancing ideas and policies that will match the vigor and creativity of our students.

BIOGRAPHY FOR MARK KAMLET

Mark S. Kamlet is provost and senior vice president of Carnegie Mellon University and professor of economics and public policy. He received a B.S. in Mathematics from Stanford, and an M.S. in Statistics, M.S. in Economics and Ph.D. in Economics from the University of California at Berkeley. He has taught at Carnegie Mellon since 1976. He has served as head of the Department of Social and Decision Sciences, associate dean of the College of Humanities and Social Sciences, and for eight years served as dean of the H. John Heinz III School of Public Policy and Management.

Kamlet's research areas are in the economics of health care, quantitative methodology, and public finance. He has over 75 published papers, and has received the outstanding publication award from the Association of Public Policy and Management for his work on the Federal budgetary process.

He has served on a U.S. Public Health Service panel to produce national guidelines on applying cost-effectiveness analysis in health care; and on three National Institute of Health consensus panels to make recommendations on national policies relating to prenatal genetic testing; neonatal screening; and end-of-life care. He has served on the Institute of Medicine's Board on Population Health and Public Health Practice, National Institute of Health's Public Access Working Group, and various consensus panels for the Centers for Disease Control.

Kamlet is chairman of the board of directors of Carnegie Learning, Inc., past chairman of the board of Carnegie Technology Education, Inc. He has served on numerous boards of regional not-for-profits, including currently Pittsburgh Parks Conservancy, the Institute for Transfusion Medicine, The Western Pennsylvania Hospital and Highmark Inc. He served on the committee that drafted the rules and procedures for the new Allegheny County Executive and County Council, chaired the transition team for Allegheny County in the area of information technology, and chaired the first advisory board for the County Chief Executive on economic development.

Chairman WU. Thank you very much, Dr. Kamlet.

Dr. Atkinson, please proceed.

STATEMENT OF DR. ROBERT D. ATKINSON, PRESIDENT, THE INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION (ITIF)

Dr. ATKINSON. Thank you, Chairman Wu, Mr. Smith and other Members. It is a pleasure to be here.

I want to start by making, I think, a simple but very important point. In a report that we issued last year called The Atlantic Century, we benchmarked the United States against 39 other nations or multi-nation regions on 16 different indicators of competitiveness and innovation; factors like corporate R&D, government R&D, venture capital, new business startups, number of scientists and engineers and the like. What we found was that in 2000, the United States was by far the world leader. Our closest competitor was significantly below us in overall ranking and score, and that

was Sweden. Unfortunately, by 2009, when we released the report, we had fallen from number one to number six behind counties like Denmark, Sweden, South Korea and some others.

The reason we fell so much and so fast is because we ranked 40th out of 40 nations or regions in change. In other words, we were dead last in progress on these factors. Other nations expanded their corporate and government R&D faster. Other nations expanded their number of scientists and engineers faster. They expanded their venture capital faster. So while a lot of that is due principally to the fact that in the last decade or so a wide array of other countries have woken up to the fact that they need to be competitive in innovation. Just a simple factoid on that. In the early 1990s the United States had the most generous research and development tax credit in the world. According to the most recent OECD data, we are 17th out of 30 OECD [Organization for Economic Co-operation and Development] nations in R&D tax credit generosity, and that is just one example of many kinds of policies.

Why do we care about this? Why is it important? I would actually argue that we can trace at least a portion of the cause of the recent financial crisis to this trend we have seen in innovation. We had an enormous amount of money in the United States looking for a home, money coming in from overseas including China, and it was looking for a place to be invested and there just weren't enough good investment opportunities of things we would consider good, i.e., innovation, and so the money ended up going into essentially bad consumption opportunities of subprime mortgages and other kinds of housing investments, which did nothing to promote U.S. long-term productivity or innovation and essentially, as we learned, was unsustainable. So I think there is a connection between the financial crisis and the lack of innovation or the suboptimal amount of innovation.

I think the second key point here, though, is that innovation can play a key role in driving jobs in the future. One of the reasons is not just because you can get high-tech jobs and innovation-based jobs that export and pay more, but more importantly for what Keynes once talked about is the key to capitalist economies working is the "animal spirits of capitalism." People have to have faith and optimism that there is going to be a better tomorrow, and innovation is a key enabler of that optimism to occur.

So what do we need to do? Let me just say, money is important but I don't think money is enough. I think one of the most important changes we need to make in our national innovation policy system is, we need to increasingly put partnerships and collaboration at the center of it. It is not just enough to give money to NSF or other agencies and do individual projects. We need to think about systemic partnerships, and we lay out and propose several recommendations in the testimony on some of those. A few examples—science and technology STEM [Science, Technology, Engineering and Mathematics] high schools. There are a number of these STEM high schools around the country. They partner with high-tech companies. They do a great job of educating kids in science. One locally here is Thomas Jefferson High School in Northern Virginia—there are a number of these. But there aren't enough of them, and what we would propose is that there is a role for NSF

funding to help expand the number of these specialty math and science high schools.

I think one of the key areas that we lack right now, and Dr. Kamlet had alluded to this, is we do an OK job of funding basic research. Where we fall down, though, is sometimes translating that research into commercial opportunities, and you have some leading institutions including Carnegie Mellon, MIT, Stanford, and Georgia Tech who do a very good job of that but they are the outliers. We need a national system that really helps all universities and Federal laboratories do a better job there. One of the proposals we have made is for a new kind of SBIR. We call it an SCNR, "Spurring Commercialization of Our Nation's Research," which would take a small portion of Federal R&D funds, about 0.15 percent, allocate that to universities and Federal labs and states to do this kind of bridging and commercialization.

Another component, I think Dr. Kamlet alluded to this, we have proposed a collaborative R&D tax credit. Many countries in the last five years have created special, more generous credits if you are funding research at universities or Federal laboratories because that research spills over.

And two final things. One, we think it is important that Federal research do a better job of supporting sector-based collaborations. We have got a very good one now in a program called the Focus Center program that the semiconductor industry and DARPA fund. It is a very, very good program, but it is only one program. So we need to be working more on sector-based efforts where industry comes to the table with ideas and money and the Federal Government helps match that, and we need to do a better job of supporting the state and local efforts that are trying to revive the U.S. economy through innovation-based economic development. They are very good efforts in many cases but they are underfunded. One way to do that, but certainly not the only way, would be to create as we have proposed with the Brookings Institution, a National Innovation Foundation to support that.

The final proposal or suggestion would be, one of the things many countries have done in the last few years is create a national innovation strategy to look more in a detailed way where they are strong, where they are weak, what other countries are doing. I think it would behoove us to also do something like that akin to the national broadband strategy but for innovation. Thank you.

[The prepared statement of Dr. Atkinson follows:]

PREPARED STATEMENT OF ROBERT D. ATKINSON

Mr. Chairman, Mr. Smith, and Members of the Committee, I appreciate the opportunity to appear before you to discuss the critical question of U.S. innovation leadership and what the Federal Government can do about it.

The United States is no longer the global innovation leader and our rank is rapidly slipping. The effects are seen in increased trade deficits, relatively lower increases in standards of living, higher unemployment and even the severity of the current economic crisis. While ultimately businesses and other organizations (e.g., universities) will have to take the lead in driving innovation, the Federal Government can and should take a much more proactive role. As I describe below, Congress can take a number of important steps, including: ensuring that USTR takes a more aggressive role in trade enforcement, expanding the R&D credit, promoting science, technology, engineering and math (STEM) skills and increasing support for research and most importantly research commercialization. In addition, we encourage the Committee to particularly consider two ideas discussed in more detail below:

the creation of a national innovation and competitiveness strategy and the establishment of a National Innovation Foundation, akin to the National Science Foundation (NSF), but for innovation.

What is at Stake: Why is Innovation Important?

In recent years, a growing number of economists have come to see that it is not so much the accumulation of more savings or capital that is the key to improving standards of living; rather it is innovation-the creation and adoption of new products, services, processes, and business models.[1] When economists Kienow and Rodriguez-Clare decomposed the cross-country differences in income per-worker into shares that could be attributed to physical capital, human capital and total factor productivity, they found that more than 90 percent of the variation in the growth of income per worker was a result of how effectively capital is used (e.g. innovation), with differences in the actual amount of human and financial capital accounting for just 9 percent.

Innovation is also essential if we are to create a future of better jobs for all Americans. Properly conceived, innovation is not just about creating more jobs for engineers and managers in high technology industries. It is also about providing more and better training for incumbent workers in manufacturing and "low-tech" services and reorganizing work processes so that their companies can perform better. Boosting innovation leads to higher real wages for American workers, and in the moderate- to the long-term, (and often in the short-term as well) leads to more jobs. Innovation, properly conceived, also benefits not just the notable high-tech regions of the nation, but all regions.

The growth of international trade also makes it increasingly important for the United States to innovate to maintain its standard of living. Low-wage nations can now more easily perform labor-intensive, difficult-to-automate work in manufacturing and in a growing share of services. Indeed, it has become difficult for the United States to compete in such industries as textiles and commodity metals. Notwithstanding the efforts of countries like China and India to compete in advanced technology industries, for the foreseeable future their competitive advantage should remain in more labor-intensive, less complex portions of the production process.[2]

By contrast, the United States' primary source of competitive advantage should be in innovation-based activities that are less cost-sensitive. To illustrate, a software company can easily move routine programming jobs to India where wages are a fraction of U.S. levels. There is less economic incentive for moving advanced programming and computer science jobs there because innovation and quality are more important than cost in influencing the location of these jobs. Likewise, an auto company can easily move production of commodity car parts to China. But the case for moving advanced research and development or production of complex, technology-driven parts (such as drive trains) there is weaker.

Nor does this mean that the United States must inevitably cede entire industries to low-wage countries. Even in industries such as apparel and textiles, which are dominated by labor-intensive production, some firms have carved out innovation-based product niches (e.g., high-fashion articles whose designs change rapidly or textiles made of advanced materials) that make it possible for them to produce in the United States. Moreover, with sufficient productivity growth, companies can offset the cost of high U.S. wages, enabling them to produce in the United States at costs equal to or below those of low-wage countries.

The United States Led in Innovation from WWII to the End of the 20th Century

Prior to World War II, it could be argued that Europe, and in particular Germany and Great Britain, led in innovation. However, since World War II until the early part of the last decade, the United States led the world in innovation. A range of statistics consistently showed this. We were leading on patents, corporate R&D, Nobel Prize winners, high tech exports, etc. Indeed, as the Information Technology and Innovation Foundation (ITIF) documented in a report, *The Atlantic Century,* released last year, the United States was ranked first among 40 leading nations in 2000 according to an amalgam of 16 innovation-based competitiveness factors (such as funding of corporate and government R&D, venture capital as a share of GDP, new businesses created, number of scientists and engineers as a share of the workforce, etc.). And our lead was not slight; we were far ahead of our closest two rivals (Sweden and Singapore).

What Factors Helped the United States Lead in Innovation-based Competitiveness?

There are a number of policy and non-policy factors which contributed to the United States lead in innovation from the 1940s through to the 2000s.

On the non-policy side, a key factor was our large and growing market which enabled U.S. corporations to have large enough markets to invest in R&D at the scale needed to drive innovation. The large market (both in number of consumers but also in their higher incomes) also meant that U.S. firms could gain economies of scale and economies of learning that enabled costs to be driven down and new generations of products and services to become profitable faster. For example, in 1960, the number of automobiles sold in Los Angeles County alone exceeded all those sold in Asia or South America.[3]

Indeed, the U.S. led the world in the application of mass production manufacturing to virtually all sectors. Numerous production innovations, including automated assembly lines, numerically controlled machine tools, automated process control systems and mechanical handling systems drove down prices in American manufacturing and led to production of a cornucopia of inexpensively manufactured consumer goods.

The United States was also the first nation to transform its innovation system into a science-based one where innovation was derived from a more fundamental understanding of underlying processes than from one of mere tinkering and mechanical trial and error. As economist Joseph Schumpeter argued in the 1940s, reflecting on the U.S. economy, "Technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways."[4] As a result, U.S. R&D expenditures skyrocketed by 400 percent between 1953 and 1964. For example, DuPont's R&D expenditures increased from around $1 million per year in 1921 to over $60 million by the mid-1950s.[5] The number of research and development laboratories increased from around 1,000 in 1927—with few doing basic research—to almost 5,000 in 1956, with many, like Bell Labs, conducting extensive basic research. As the innovation process became systematized and corporatized, engineers became more important. In 1900, engineers made up only 0.05 of the population, but by 1940, 2 out of 1,000 people were engineers, and by 1970, 6 out of 1,000 were.[6] As a result, the locus of innovation also switched from individual inventors like Edison and Bell tinkering in their garages to scientists working in corporate R&D laboratories.[7] One reflection of this is the fact that in 1901 there were 20,896 patents issued to individuals, with only 4,650 going to corporations. This evened out by the 1930s, but by the mid-1950s the corporate rate took off. By 1980, corporations obtained about five times more patents than individuals.

But our lead in scientific discovery alone was not enough to propel the United States to the lead. That required firms willing and able to make the investments needed to transform from invention to innovation and commercialization. And a key factor was the new science of management and the organization of firms able to handle large complex production systems. After WWII, new forms of corporate organization emerged, in which a top managerial cadre became empowered with the information necessary to centrally manage massive, sprawling enterprises. When the large, multidivisional company became commonplace after World War II, CEOs put in place elaborate paper-based managerial systems to coordinate these sprawling companies. Millions of new white-collar middle managers were needed to make these behemoths work. This rise of a new managerial class was one of the most profound changes resulting from the rise of the corporate economy. Indeed, after World War II, the formal discipline of management emerged. James Burnham's 1941 book, *The Managerial Revolution,* argued that the world was witnessing the emergence of a new ruling class, the managers,' who would soon replace the rule of capitalists and communists alike. Combine this with the emergence of world class business schools that educated managers who could manage innovation, and the United States had another lead over its competitors who did not embrace the 'new managerialism' until decades later.

Other factors played a role. The American inventor and entrepreneurial ethos also helped drive our innovation lead. More so than any other nation at the time, America was a place where "anyone could make it," provided they worked hard and took risks. America was able to draw on the talents of a larger share of the population to drive innovation. And related to this, in contrast to many nations, failure was not seen as a stigma from which recovery was difficult. Rather, it was a mark that someone had the fortitude to take a risk, and perhaps the second (or third, or fourth) time would be the charm. Moreover, in those days, if one wanted to remake oneself, one simply moved south or west. Indeed, the very size of our nation and the relative underdevelopment of much of the West and South until the 1970s

meant that entrepreneurs could locate in places unconstrained by the dead weight of tradition and inertia. No wonder that in the 1960s Silicon Valley instead of Pittsburgh (where the largest electronics firm in the world at the time, GE, was headquartered) became the world's innovation leader. Pittsburgh was a place where if it hadn't been tried before, it was probably because it was a bad idea. Silicon Valley was a place where if it hadn't been tried before, it probably meant it was a good idea that no one had yet before come up with. In addition, in comparison to other nations that exhibited greater institutional rigidities and hierarchies, the more flexible and collaborative U.S. innovation system provided an advantage. Compared to other nations, the U.S. innovation system has long been characterized by collaboration and cooperation, with universities working more closely with industry, small firms working with large ones, etc.

Finally, our financial system provided real advantages. Compared to other nations it was easier for entrepreneurs to get financing for new and risky ventures, and for those firms to pay back initial investors, either by issuing stocks or getting large firms to finance their acquisitions as the way to maintain a pipeline of new products.[8]

It would be a mistake to argue, though, that it was only, or even largely, non-policy factors that led to America becoming the world's innovation leader. Clearly some of our policy choices to regulate less and to be more accepting of change propelled the United States to lead.

Our relatively open borders (itself a policy factor) made the United States a mecca for talent. Welcoming the world's most skilled foreign-born scientists and engineers into the land of economic opportunity that America affords has long been one of the strengths of the U.S. national innovation system. Both the U.S. economy and the standard of living of American citizens have benefited enormously from this influx of foreign talent. AnnaLee Saxenian, a professor at the University of California-Berkeley, has shown that Indian and Chinese entrepreneurs founded or co-founded roughly 30 percent of all Silicon Valley startups in the late 1990s.[9] During this period, many of the leading scientists, managers and entrepreneurs came from other nations where opportunities were more limited and in some cases where the opportunities didn't even exist, as was the case in communist nations.

Likewise, our embrace of a light regulatory touch in the face of new technologies allowed innovators to be confident that their innovations would be able to enter the market. In contrast, regulatory regimes such as the European "precautionary principle," which sought to limit innovation until all possible effects were known, slowed innovation. And in fast-moving industries where competitive advantage is related to how quickly players get in the market and establish a position, the slower and more restrictive regulatory regimes in many other nations benefited the United States.

The overall business climate and rule of law that the United States has enjoyed has provided entrepreneurs and firms with the certainty that if they invested they could make a market-based rate of return. Likewise, the United States' leadership in promoting open markets and globalization helped the United States, at least through the 1980s, for it expanded the size of markets, allowing more dominant U.S. technology-based firms to gain even more scale and profits (allowing them respectively in turn to drive prices down even more and to invest more into research and new technology).

In addition, while the United States brought a number of anti-trust cases during this period, the emergence of a large number of large, profitable companies meant that innovations were a way that firms could charge premium prices or even gain market share from their competitors. With constrained competition and consequent market control, these companies could apply lower discount rates to new research opportunities; in essence, they were willing to take on the higher levels of risk required to pursue more radical but higher payoff technologies. As a result, many of these dominant firms used the steady flow of profits to invest heavily in their own research laboratories. They created factories for inventions that brought large numbers of scientists and engineers directly under the corporate umbrella. In the 1950s and 1960s, the central research laboratories of firms such as AT&T, GE, IBM, RCA and Xerox were corporate jewels that attracted highly productive researchers.

But proactive policies also played a key role. Perhaps the most important one was the role of government as a buyer of technology and funder of research and education. During the three decades immediately following World War II, the Federal Government's role in supporting new technologies centered on military and space imperatives. Such familiar spin-offs as mainframe computers and jet airplanes had been largely unintended consequence of government spending for the military and the space program, both in support for research in these areas and procurement of products using these technologies. Clearly the United States' lead in many technology areas, including information technology, would not have occurred without

government procurement and government support for R&D. Indeed, as late as 1992, Santa Clara County (Silicon Valley) received more defense contracts than any other county (in dollar value as a share of county economic output).

But support for research and research universities was also central in driving U.S. innovation leadership. Federal and state support meant that a large number of research universities were not only doing cutting-edge research, much of it transferred to the private sector, but also educating a regular crop of top notch scientists and engineers. Our global lead in pharmaceutical and biotech industries, for example, would not have been as strong without the significant funding provided to NIH, much of which in turn supported leading research universities.

As the United States excelled, its lead over other nations expanded, leaving the Europeans fearful of being left behind. In the 1960s, French author Jean-Jacques Setvan-Schreiber wrote the best seller, *The American Challenge,* which described an all powerful American economic system widening its technological lead and utilizing superior management ability and economies of scale to take over the European economy.

But our unparallel leadership lasted only approximately 25 years. For by the mid-1970s, evidence was emerging that the United States faced new innovation competitors. But U.S. policy didn't stand still in response to the challenges of globalization 1.0 in the 1980s (the emergence of Japan and Europe as key competitors). Indeed, significant changes occurred in Federal policies in the 1980s in direct response to the heightened international competitive pressures experienced by U.S.-based corporations. In that decade, both Congress and the Executive Branch launched a series of initiatives that were intended to mobilize public resources to accelerate the development and commercial exploitation of new technologies. These programs extended well beyond the defense and space sectors that had previously been the main areas of Federal technology policy.

These initiatives can be usefully grouped into four separate areas. First, there were a series of efforts to increase the commercial impact of research already being funded by the Federal Government, particularly in universities and government laboratories. Incentives were created for scientists and institutions to push their research discoveries into the commercial sphere either by creating new start-ups, licensing technologies to private firms or engaging in collaborative projects with business firms. The Bayh-Dole Act encouraged universities to see their research enterprise as a potential revenue source and concerted efforts were made over twenty years to shift resources in the Federal Laboratories away from weapons production and towards commercial applications.

Second, new programs were created to help finance pre-competitive research and development costs for individual firms, both startup and established firms.[10] Most prominent among these programs was the Small Business Innovation Research (SBIR) program through which government agencies set aside a small percentage of their R&D budgets for projects proposed by small firms, many of which are newly created spinoffs from university or Federal laboratories. The Advanced Technology Program (ATP) at the National Institute of Standards and Technology (NIST) and a series of initiatives at the Department of Energy provided matching funds to support particularly promising new technologies among both new and more established firms. In addition, the United States was the first nation to create a Research and Development (R&D) Tax credit in 1981.

Third, the Federal Government expanded its "in-kind" technical support to business firms trying to surmount technological barriers. The Manufacturing Extension Partnership (MEP) has helped thousands of small firms adapt to computerization and the more demanding schedules of just-in-time production. The National Nanotechnology Initiative has made a series of federally funded, university-based laboratories available to business firms that want to avoid the costs of developing their own laboratory infrastructure. Similarly, efforts by Federal laboratories to form partnerships with firms provide them with important technical support, including through the formation of Cooperative Research and Development Agreements (CRADAs).

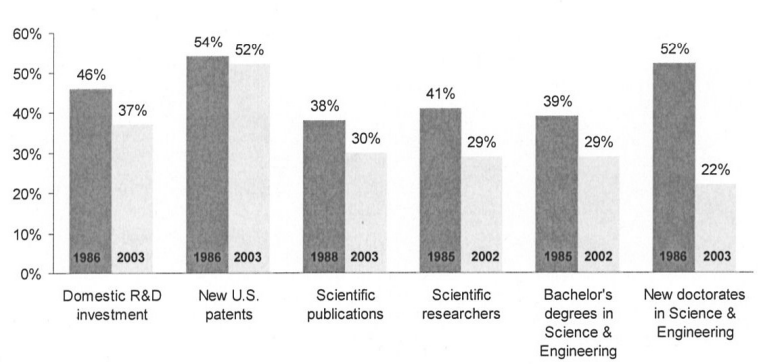
Fourth, the Federal Government played an active role in facilitating and supporting research consortia that bring together multiple firms in the same industry to solve technological problems. The passage of the 1984 Cooperative Research and Development Act made it easier for companies to collaborate. Federal investment in SEMATECH in the 1980s and the Semiconductor Focus Center Program in the 1990s helped the semiconductor industry maintain a leadership position.[11] Congress created programs at NSF to spur more collaborative research, including NSF's Engineering Research Centers, a group of 17 interdisciplinary centers located at universities and operated in close partnership with industry.

The United States Has Lost its Lead in Innovation

The combination of its policy and non-policy strengths, combined with policy and non-policy weaknesses in other nations, enabled the United States to lead in innovation for over half a century. However, changes both in the United States and abroad have meant that while the United States continues to have many strengths, there is disturbing evidence that our overall innovation lead has not only been lost, but that we are continuing to rapidly lose ground. As ITIF documented in *The Atlantic Century,* from the year 2000 to 2009, the United States slipped from number 1 to number 6 in global innovation-based competitiveness, behind nations such as Singapore, Denmark, Sweden and South Korea. The primary reason for this is that every other nation or region made faster progress than we did on a collection of 16 innovation competitiveness indicators. Overall, we ranked 40th out of 37 countries and three regions in making progress on innovation and competitiveness.

We see signs of this relative decline in innovation capacity in a wide array of indicators. The decline began at least in the 1990s with the United States' shares of worldwide total domestic R&D spending, new U.S. patents, scientific publications and researchers and bachelor's and new doctoral degrees in science and engineering all falling from the mid-1980s to the beginning of this century (figure 1), when we were still number 1. But given our strong overall lead, the declines were not enough to move us down from number 1 until this last decade.

FIGURE 1: Changes in U.S. Share of Global Totals On Various Science and Technology Indicators



Source: Council on Competitiveness

There has been a declining share of American college graduates with science and technology degrees. The United States now lags behind much of the world in the share of its college graduates majoring in science and technology. As a result, the United States ranks just 29th out of 109 countries in the percentage of 24-year-olds with a math or science degree. Although Americans (citizens and permanent residents) are getting graduate degrees at an all-time high rate, the increase in graduate degrees in natural science, technology, engineering and math fields has been minimal during the last two decades. The number of non-science and engineering degrees increased by 64 percent between 1985 and 2002, while the number of science, technology, engineering and mathematics degrees grew by only 14 percent during that period.[12]

The United States ranks only 14th among countries for which the National Science Foundation tracks the number of science and engineering articles per million inhabitants. Sweden and Switzerland produce more than 60 percent as many science and engineering articles in relation to the size of their populations than does the United States.[13]

The United States ranks only seventh among OECD countries in the percentage of its GDP that is devoted to R&D expenditures (2.6 percent), behind Sweden (3.9 percent), Finland (3.5 percent), Japan (3.3 percent), South Korea (3.0 percent), Switzerland (2.9 percent), and Iceland (2.8 percent), and barely ahead of Germany and Denmark (2.5 percent each).[14] One reason explaining this is that the United States is one of the few nations where total investments in R&D as a share of GDP fell from 1992 to 2005 (largely because of a decline in public R&D support).[15] Moreover, corporate-funded R&D as a share of GDP fell in the United States by five percent

from 1999 to 2006, while in Europe it grew by two percent and in Japan it grew by 12 percent.[16]

We also see the evidence of our decline in innovation-based competiveness in other areas including our trade performance. The trade deficit represents perhaps the most visible manifestation of the global challenge. At five percent of GDP in 2008, the current account deficit is at extremely high levels both in absolute terms and relative to the size of our economy.[17] The traditional U.S. trade surplus in agricultural products is nearing zero and in high-technology products has already turned negative. Meanwhile, our surplus in services trade is small and only holding relatively steady. Moreover, the U.S. trade surplus in services is only 17 percent of the overall trade deficit in goods.

Moreover, companies are increasingly shifting R&D overseas. For example, R&D expenditures from U.S.-based MNCs in emerging Asian markets increased from five percent to 14 percent between 1995 and 2006.[18] In the last decade, the share of U.S. corporate R&D sites in the United States has declined from 59 percent to 52 percent, while the share in China and India, specifically, increased from 8 to 18 percent.[19]

We also see it in the decline in U.S. manufacturing output. The United States has experienced a hollowing out of many advanced production supply chains, as more advanced manufacturing has moved offshore than has expanded in the United States. I recently spoke with the CEO of a major U.S. high technology company about a new product line they were introducing. I asked him where he was sourcing the very advanced display that was being incorporated in the device. His response was "we looked long and hard around the United States to see if we could source it here. We couldn't find any company with the capability of producing here, so we ended up sourcing it in Taiwan."

This hollowing out of supply chains is overlooked by many economists because the national economic accounts that track manufacturing output provide a misleading picture of the health of U.S. manufacturing by overstating output, particularly in the computer and semiconductors industry. According to the Department of Commerce's Bureau of Economic Analysis, manufacturing output as a share of GDP has stayed somewhat constant between 1994 and 2008, at around 13.7 percent.[20] But drilling down to more detail causes a different picture to emerge. Over the last 25 years, the share of non-durable manufacturing output peaked around 1993 and has declined from around seven percent to 4.7 percent of GDP in 2008. The share of durables, in contrast, increased to just over nine percent in 2007, with a very slight decline in 2008, leading many to the rosy conclusion that while manufacturing employment may have declined, manufacturing output is still strong and therefore that employment declines were due only to the higher levels of productivity in manufacturing relative to the rest of the economy. But taking out computers and electronic products (NAICS code 334) shows a very different picture, with durable goods output share declining from seven percent in 1998 to 5.3 percent in 2008. Overall manufacturing output minus computers and electronic products declined from 13 percent of GDP in 1998 to just 9.7 percent in 2008. Defenders of the status quo will respond that the proper measure is overall manufacturing, not manufacturing minus computers. But does anyone really think that the real inflation-adjusted value added of computers and electronic products really doubled between 2003 and 2007, which is what the BEA numbers suggest? The problem is that BEA counts output of computers based on improvements in Moore's law and when processing power doubles every 18 months or so it counts that in the value-added. But this clearly overstates output and provides an extremely misleading picture of the real health of the U.S. manufacturing sector. For those who want to play down the threat to the U.S. manufacturing base, these statistics provide reassuring, if false, comfort.

Factors Contributing to our Relative Decline in Innovation-based Competitiveness

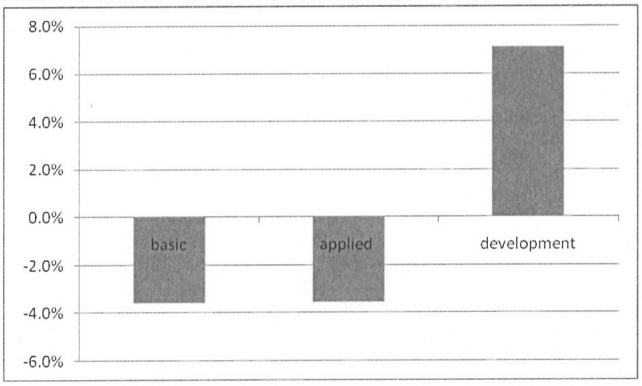
There are a number of factors which have contributed to the United States' relative decline in innovation-based competitiveness. Many point to globalization. At one level there is no doubt that with the emergence of globalization and the relatively faster growth in income of many nations to "catch up" to the United States, one would expect to see the global share of U.S. economic output fall. And it is certainly true that as some advanced nations began to catch up to the United States (in part by emulating our policies, as described below) the U.S. share of global innovation output (e.g., R&D and patents) would also fall, although by less than overall economic output since the United States should actually be increasingly specializing in innovation-based activities as more routine-based production shifts offshore. But there was nothing preordained about the United States falling from number 1 in

2000 to number 6 in 2009. The United States can and should remain the global innovation leader.

So what happened? As in explaining our success, non-policy and policy factors have played a role. There are a number of non-policy factors that appear to be at work. First, the evolution of U.S. financial markets has placed mounting pressure on large corporations to prioritize increasing short-term returns to shareholders over growth or investments with longer-term payoffs. And related to this, the market environment has become much more competitive.

On the one hand, this has disciplined firms into being more efficient. But at the same time it has led many firms to seek short-term cost reductions (often through moving to lower cost locations) even if similar or even greater cost reductions through innovation could be achieved but over a slightly longer period of time. Likewise, these new financial pressures have forced many firms to reallocate their research portfolios more toward product development efforts and away from longer term and more speculative basic and applied research. From 1991 to 2007, basic research as a share of total corporate R&D conducted in the United States fell by 3.6 percentage points, while applied research fell by roughly the same amount, by 3.5 percentage points. In contrast, development's share of corporate R&D increased by 7.1 percentage points, as figure 2 shows.

FIGURE 2:
BETWEEN 1991 AND 2007, THE SHARES OF TOTAL CORPORATE R&D DEVOTED TO BASIC AND APPLIED RESEARCH DECLINED WHILE THE SHARE DEVOTED TO DEVELOPMENT INCREASED



Source: Authors' analysis of National Science Foundation data

We see this focus on the shorter term in the venture capital industry. As the venture capital market has matured, firms have found it more profitable to invest in larger deals and less risky later-stage deals. Even though the overall amount of venture capital has grown since the mid-1990s, the actual amount invested in startup- and seed-stage venture deals is smaller today than a decade ago, and a smaller percentage of venture funding now goes to early-stage deals (the stage just after seed-stage).[21] The result is a gap between the completion of basic research and applied R&D.

When it comes to policy, it is important to focus both on the change in policy in the United States and externally. Externally, as we discuss below, nations put in place aggressive technology and competitiveness policies to lure internationally mobile technology investment. U.S. firms are now competing against firms in a growing number of national economies in which their governments actively help them compete.

Over the last 15 years in particular, a large number of other nations have woken up to the fact that they need to compete for internationally mobile high technology manufacturing, and they have put in place policies that reflect that determination, such as more generous research and development tax treatments and stronger government support for all stages of research. In contrast, the United States has lagged behind, believing that it needed to do little since it had long been the global innovation leader. In the early 1990s, for example, the United States had the most generous research and development tax credit among the 30 OECD nations. Now, be-

cause other nations have expanded their R&D tax incentives, the U.S. rank has fallen to 17th.

In response to increased global competition for internationally mobile economic activities, most nations have established competitiveness policies, including more competitive corporate tax codes. In the early 1980s, the average statutory tax rate amongst OECD nations was nearly 50 percent; by 2001 the rate had fallen to under 35 percent. Some formerly high tax nations have reduced their taxes dramatically. For example, the statutory corporate tax rate in Sweden in 1982 was 60 percent; by 1999 it had been reduced to 28 percent. Overall, average corporate tax rates have declined by at least 15 percentage points in leading industrialized nations over the last 30 years. Not only have corporate tax rates declined, but a growing number of nations, particularly Asian nations, use targeted tax incentives (such as tax holidays on new plants) to attract internationally mobile investment. The U.S. statutory rate has not changed since 1986, and the Federal Government does not provide tax incentives to attract or retain international investment.

We see the same trend in other areas. Among 36 nations, the United States ranked just 21st in the growth of government investment in R&D from 1999 to 2006, with a growth rate of just 20 percent the average of the other nations. The major reason for this slippage has been a slowdown in Federal R&D investment. Since the mid-1990s total Federal R&D spending grew at a sluggish 2.5 percent per year from 1994 to 2004—much lower than its long-term average of 3.5 percent growth per year from 1953 to 2004.[22] Indeed, the United States is one of only a few nations where total investment in R&D as a share of GDP actually fell from 1992–2005, largely because of that decline in public R&D support.[23] When U.S. R&D intensity is compared to other OECD countries, we find that at 2.6 percent of GDP devoted to R&D investment, the United States ranks only seventh in R&D intensity, behind a list of countries including Japan, South Korea, Finland and Sweden.[24] In more recent rankings (2006) from the OECD, the United States placed only 22nd in the fraction of GDP devoted to nondefense research.[25]

Finally, while many nations have practiced "good" innovation policy, many have also put in place "bad" innovation policy: high-tech mercantilism. Indeed, a key factor in the loss of U.S. innovation leadership has been the dramatic increase in technology-oriented trade protectionism engaged in by many U.S. competitors. While U.S. markets are generally open, the same cannot be said for many other nations. Many nations, and not just China, manipulate their currency as a way to subsidize exports and raise the price of imports. On top of that they use an array of tariff barriers to keep out U.S. exports. But these nations go further, engaging in a kind of protectionism 2.0. This involves aggressive anti-trust enforcement, particularly against U.S. high tech companies (witness foreign actions taken against U.S. tech companies like Microsoft, Intel and Qualcomm); technology standards manipulation (the Chinese alone have developed over 15 proprietary technology standards designed to keep out U.S. IT products); turning a blind eye to and even engaging in rampant intellectual property theft (over 85 percent of software in China is pirated, while many nations attempt to force U.S. pharmaceutical companies to transfer intellectual property in return for market access); and huge government subsidies to prop up high-tech exporters (without EU government subsidies, Airbus would have nowhere near the global market share it does).

But even absent what other nations have done, the U.S. relative position would have declined because of policies at home. One policy area that has been cited by many is K–12 education. While there is no doubt that improving the quality of K–12 education will have some positive benefit on our innovation-based competitive position, it would be a mistake to believe that fixing K–12 will be the silver bullet for innovation. K–12 quality has not been the major reason for the precipitous and troubling decline in U.S. innovation leadership. In fact, while the U.S. competitiveness position has declined relative to other nations, at least by one measure, our educational performance has not. For 20 nations for which there are comparable data, between 1999 and 2007 the United States ranked fourth in improvement in 8th grade math scores an sixth out of 25 nations in 81' grade science scores according to TIMMS (Trends in International Mathematics and Science Study). The United States has also made greater improvement in 8th grade science scores than several international leaders such as Japan, Sweden, Norway and Singapore between 1999 and 2007.

The United States does less well on the OECD's PISA (Programme for International Student Assessment) test, which focuses more on measures of application of learning to real world situations than does TIMMS. Still, the U.S. performance on PISA has not been so bad as to indicate our economic decline. In reading, math and science, U.S. 15-year-olds in 2000 (who would now be 25-years-old and entering the workforce) performed about as well on average as 15-year-olds in the 27 partici-

pating OECD countries and ahead of the 4 non-OECD nations. Compare the United States and Denmark. Denmark outperformed the United States in innovation-based competitiveness, ranking fifth in progress, compared to our last place rank. Yet, in 2000, U.S. 15-year-olds outperformed Danish 15-year-olds on reading, math and science. Likewise, U.S. 15-year-olds did better than 15-year-olds in Germany, Spain, Russia and Brazil, all of which made faster progress on competitiveness. Let us also remember that U.S. college education levels are at historic highs. In 2007, 46 percent of high school graduates between the ages of 18 and 24 were actively enrolled in higher education. This is hardly the stuff of catastrophic failure.

An area of more concern is the reduced investment in innovation infrastructure, including research. Total Federal funding for R&D declined as a share of GDP from 1985 to 2004. To restore Federal R&D support as a share of GDP to its 1993 level, we would have to increase Federal R&D spending by 50 percent, or over $37 billion. Federal investment in most of the programs that focus most directly on innovation promotion have declined or grown more slowly than the economy overall. Between 1998 and 2006, the budgets for the Advanced Technology Program, the Manufacturing Extension Partnership, the Office of Science and Technology Policy, and the Industrial Technologies Program declined in nominal terms, while that of NSF's Engineering Research Center program grew at less than one-fifth the rate of GDP growth. Funding for NSF's Partnerships for Innovation also grew more slowly than GDP since the program began operating in 2000. And while our public and private research universities used to be the envy of the world, 20 years of underfunding by state governments have meant that many public research universities have fallen in capabilities relative to private research universities.

Adequately investing in and developing innovation-enhancing policies is crucial to national innovation competitiveness, as Professors Jeffrey Furman and Richard Hayes found in a study of the national innovation capacity (an economy's potential for producing a stream of commercially relevant innovations) of twenty-three countries from 1978 to 1999.[26] Starting with the year 1979, they classify countries as either world-leading innovators (the United States, Germany, Japan), middle-tier (Great Britain, France, Australia), third-tier (Spain, Italy), or "emerging" innovators (Ireland, Taiwan) based on countries' patenting activity per capita, a proxy for commercialized innovations.

A number of these "emerging innovators"—among them Ireland, Finland, Singapore, South Korea, Denmark and Taiwan, in particular—achieved remarkable increases in innovative output per capita from 1978 to 1999, moving to the world's technological frontier and overtaking the innovative capacities of many mid- and third-tier countries, including Great Britain, France and Italy, whose economic conditions started off much more favorably in the early 1980s. Furman and Hayes conclude that innovation leadership among countries requires not only the development of innovation-enhancing policies and infrastructure, such as strong IP protections, openness to trade, highly competitive markets, and strong industry clusters, but also a commitment to maintaining substantial financial and human capital investments in innovation.

Additionally, Federal agencies have not responded as nimbly as they should too many of the changes in the innovation environment. For example, the U.S. Patent and Trademark Office (PTO) used to be the envy of other nations around the globe for its effectiveness and efficiency. But today backlogs at the PTO mean that most patent applicants will wait years before finding out if their invention is granted a patent.

Moreover, even as services innovation has become much more important, U.S. innovation policy has not responded. U.S. innovation policy is largely focused on innovation in goods-producing industries, e.g., developing a new energy source or coming up with new materials. In the past, when goods production was a much larger share of the economy than it is today, such a focus made more sense. But in an economy where more than 80 percent of civilian jobs lie in service-providing industries, the lack of focus on services innovation makes little sense. The emerging discipline of service science brings together ongoing work in computer science, operations research, industrial engineering, business strategy, management sciences, social and cognitive sciences, and legal sciences to develop the skills required in a services-led economy.[27]

Finally, as the U.S. innovation system has spread out to all states and corners of the nation, the Federal system has remained national in scope. Washington is often far removed from the firms and other institutions that drive innovation. This is particularly true for small and mid-sized firms. In contrast, state and local governments and metropolitan-level economic developers have a long track record of creating organizations that work more closely with firms. Unfortunately, most existing Federal programs do not work through or in collaboration with state or local

governments or regional organizations, which are often more flexible and less remote from production processes. Indeed, there is very little appreciation in Washington for the fact that virtually every state has in place technology-based economic development programs.[28] Federal program managers and policymakers all too often seem to assume that there is one uniform national economy in which regional agglomerations are at best a sideshow.

What Can We Learn From Other Nations?

Many forward-thinking countries have made innovation-led economic development a centerpiece of their national economic strategies during the past decade. These nations know that moving up the value chain to more innovation-based economic activity is a key to boosting future productivity, and that losing the competition can result in a relatively lower standard of living as economic resources shift to lower-value-added industries. These countries are implementing coordinated national innovation agendas that boost R&D funding, introduce policy changes and government initiatives that more effectively transfer technologies from universities and government laboratories to the private sector for commercialization, and ensure that immigration policies support innovation.

While many nations have taken the innovation challenge to heart and put in place a host of policies to spur innovation, the United States has done little, consequently falling behind in innovation policies and in innovation performance as well. We see this gap in at least four main areas: programs to establish civilian technology and innovation promotion agencies, services innovation initiatives, tax incentives for research and development, and policies regarding high-skill immigration.[29]

1. Civilian Technology and Innovation Promotion Agencies

A number of advanced countries are well ahead of the United States in creating national agencies that support innovation. In recent years, Finland, France, Iceland, Ireland, Australia, Japan, the Netherlands, New Zealand, Norway, South Korea, Canada, Germany, Taiwan, Switzerland and Great Britain have all either established or significantly expanded separate technology-and innovation-promotion agencies. Other nations, such as Denmark, Sweden and Spain, have longstanding agencies of this type.[30] All these countries have science- and university-support agencies similar to America's National Science Foundation, which largely fund basic research, universities and national laboratories. But these countries realized that if they were to prosper in the highly competitive, technology-driven global economy, they needed specifically to promote technological innovation, particularly in small and mid-sized companies and in partnership with universities.

Perhaps the most ambitious of these efforts is Tekes, Finland's National Agency for Technology and Innovation. In the last two decades, Finland has transformed itself from a largely natural resource-dependent economy to a world leader in technology, with Tekes a key player in the country's transformation. Affiliated with the Ministry of Employment and the Economy, Tekes funds many research projects in companies, multi-company partnerships, and business-university partnerships. With a budget of $560 million (in a country of only 5.2 million people), Tekes works in partnership with business and academia to identify key technology and application areas—including nano-sensors, ICT and broadband, health care, energy and the environment, services innovation, and manufacturing and minerals—that can drive the Finnish economy. Tekes also operates a number of overseas technology liaison offices that conduct "technology scanning," seeking out emerging technologies bearing on the competitiveness of Finnish industries, and sponsors foreign outreach efforts to help its domestic companies partner with foreign businesses and researchers.

Similarly, Japan's New Energy and Industrial Technology Development Organization (NEDO) is a quasi-public agency that receives its $2 billion budget from the Ministry of International Trade and Industry. Great Britain's new Technology Strategy Board is a non-departmental public body (similar to an independent government agency in the United States) whose mission is to drive forward the government's national technology strategy. In South Korea, the Korea Industrial Technology Foundation, established in 2001, engages in a wide range of technology activities, including providing training to develop industry technicians and cooperating with international entities to promote industrial technology development. A host of other nations have similar bodies dedicated specifically to promoting innovation and competitiveness.[31]

Most foreign innovation-promotion agencies provide grants to companies for research, either alone or in consortia, including in partnership with universities. All support university-industry partnership grant programs, whereby companies or

business consortia can receive grants (usually requiring matching funds) to partner with universities on research projects. Vinnova, Sweden's innovation-promotion agency, gives most of its grants to research consortia involving companies and universities.

Most agencies focus their resources on specific areas of technology. For example, by working with business and academia, Tekes has identified 22 key technology areas to fund. Many foreign programs have expanded their focus to include service sector innovation. One of Tekes' focus areas is innovation in services, including insurance and finance, retail and wholesale trade, logistics, and knowledge-intensive business services. The United Kingdom's Technology Strategy Board is working with knowledge-intensive industries such as creative and financial services in addition to the high-tech and engineering sectors. Most programs insulate their grant making from political pressure by using panels of outside experts to review grant application, just as our National Science Foundation and the Technology Improvement Program (TIP) do.

Most agencies also support national sector-based activities that bring together researchers in the private, non-profit and public sectors. For example, the UK's Technology Strategy Board established its Innovation Platforms program to bring together government stakeholders and funders, engage with the business and research communities to identify appropriate action, and align regulation, government procurement and other public policies to support innovative solutions. To date, this program has identified two priority areas, intelligent transport systems and network security.[32]

One of the benefits of these programs is that they not only fund research projects but also facilitate networking and collaboration. For example, Tekes brings together in forums many of the key stakeholders in the research community. For each of its 22 technology areas there are networking groups of researchers. In addition, Tekes publishes a description of each project it funds. Through these processes, researchers learn more about research areas and gain opportunities to collaborate. Many agencies also work with industry on "roadmapping" exercises, whereby key participants (industry and academic researchers and government experts) identify technology challenges and key areas of need over the next decade. They then base their selection of research topic funding on the results of the roadmap exercise. The UK's Technology Strategy Board is funding over 600 collaborative business-university research projects which have been launched over the past two to three years. Like Tekes, it is also responsible for more than 20 industry-and technology-based knowledge transfer networks, with more being established.

Foreign innovation-promotion agencies do not limit their activities to R&D support. The Danish Technological Institute and Iceland Technology Institute, for example, help small and mid-sized firms upgrade their technologies and business processes. Enterprise Ireland offers workforce training grants to small and mid-sized businesses.

Many innovation-promotion agencies also have foreign outreach efforts to help domestic companies partner with foreign companies or researchers. For example, Tekes has a number of overseas offices that act as technology liaisons including in Washington, DC, Singapore and South Korea. Indeed, 40 percent of Tekes-funded projects involve international collaboration. Spain's innovation-promotion agency, CDTI, also helps Spanish businesses find partners in other nations and provides up to 60 percent funding to the participating Spanish firm.

Most of these organizations are affiliated with, but separate from, national cabinet-level agencies similar to our Commerce Department. However, some are independent government agencies or government-sponsored corporations. The Danish Technological Institute is a private, nonprofit organization. In virtually all cases, though, these nations have made an explicit decision not to place their innovation-promotion initiatives under the direct control of large government departments. Although most innovation-promotion agencies are affiliated with those departments, they usually have a substantial degree of independence. It is common for these agencies to have their own executive director and a governing board of representatives from industry, government, university, or other constituency groups. For example, Japan's government recently made a conscious choice to establish NEDO as an autonomous agency because it realized that MITI, as a large government bureaucracy, did not have the flexibility needed to manage such a program. NEDO is governed by a board of directors, with the Chair appointed by MITI and members from industry, universities and other government agencies. Similarly, Tekes is affiliated with the Ministry of Trade and Industry but has its own governing board that includes national and regional government, businesses and union representatives.33 The Technology Strategy Board, begun in 2004 as a unit of the Department of Trade and Industry, was established in 2007 as an executive non-departmental public

body. While it is now affiliated with the Department for Innovation, Universities and Skills, it is governed by a board made up mostly of technical experts from industry.[34]

One reason for structuring innovation-promotion agencies this way is that they have more flexibility, including the ability to pay salaries high enough to attract staff from the business world and the ability to employ some staffers who are on leave from positions in private business. For example, about one-third of the NEDO staff is from industry and one-third is from universities, while the remaining third is full time NEDO staff. Rotating in outside staff helps keep the agency in touch with current business practices and cutting-edge technology. (For similar reasons, NSF employs some people who are on leave from academic and research positions outside the Federal Government.) The Technology Strategy Board has been able to source a fairly large share of its staff from industry, enabling it to have the kind of expertise that would be difficult without this ability. In addition, independent government bodies can adapt more quickly than those that are subject to the tight control of larger agencies. It is easier for them to start new initiatives and abolish less effective ones. Likewise, many national technology agency programs are able to pay employees more than the standard government salaries, enabling them to attract higher quality individuals, often with industry experience. Nevertheless, most of these agencies are fairly lean. For example, Tekes, with a budget equivalent to $560 million, has a staff of just 300.

To be effective, these agencies need to be flexible and able to work closely with industry. For this reason they are less bureaucratic than traditional ministries or departments. As the UK government notes, "As separate legal entities, non-departmental public bodies can operate more flexibly than executive agencies, entering into partnerships and taking commercial and entrepreneurial decisions." Moreover, "their distance from government means that the day-to-day decisions they make are independent as they are removed from ministers and civil servants."[35] Foreign innovation-promotion agencies today are a far cry from the strongly directive Japanese MITI of the 1980s. They do not try to decide the path of business innovation and then induce firms to follow that path. Instead, they exemplify the cooperative, facilitative government role that is needed to address the market failures that hamper the innovation process.

If the United States wanted to match Finland's outlays per dollar of GDP in innovation-promotion efforts, it would have to invest $34 billion per year. While other nations invest less in their innovation-promotion agencies than Finland, they still invest considerably more than the United States. As a percent of their countries' GDPs, Sweden spends 0.07 percent, Japan 0.04 percent and South Korea 0.03 percent on their innovation promotion agencies. To match these nations on a per-capita basis, the United Sates would have to invest $9 billion to match Sweden, $5.4 billion to match Japan, and $3.6 billion to match South Korea.[35] It is astounding that economies a fraction the size of the United States spend more on innovation-promotion in *actual dollars,* let alone as a percentage of their economy.

But compared with other industrialized democracies, the U.S. government invests relatively little in innovation-promotion efforts. In fiscal year 2006, the Federal Government spent a total of $2.7 billion, or 0.02 percent of gross domestic product, on its principal innovation programs and agencies: the National Institute of Standards and Technology's Advanced Technology Program and Manufacturing Extension Partnership, the White House's Office of Science and Technology Policy, three NSF-administered innovation programs (Small Business Innovation Research, Small Business Technology Transfer and Industrial Technologies Program), and the Department of Labor's Workforce Innovation Regional Economic Development (WIRED) program.

This places U.S. industries and corporations operating alone at a disadvantage against foreign corporations that benefit from coordinated and enlightened national strategies among universities, governments and industry collaborations to foster competitiveness. For example, the Japanese government has recognized advanced battery technology as a key driving force behind its competitiveness, and views battery technology as an issue of "national survival."[37] It is funding Lithium-ion battery research over the five-year period from October 2007 to October 2012 at $275 million (¥25 billion), and longer term has committed to a 20-year Li-ion battery research program. Germany's government will provide a total of €1.1 billion ($1.4 billion) over ten years to applied research on automotive electronics, lithium ion batteries, lightweight construction, and other automotive applications.[38]

2. Services Innovation Initiatives

As services increasingly drive employment, productivity, and economic growth, a number of countries have developed explicit national services innovation policies fo-

cused on spurring innovation in the services sectors of their economies. Policymakers in these countries have recognized that knowledge of services innovation has largely been informed by studies of the manufacturing sector, and acknowledged the need to tailor unique measures to the needs of services firms and industries.[39]

The focus on service innovation began in the mid-2000s with a coterie of small Northern European countries—Finland, Denmark, Norway, The Netherlands and Sweden—and has since grown to include additional small countries in Europe and Asia (Taiwan, Ireland and Singapore) and large nations (Great Britain, Canada and Germany). Finland was the first to implement a national services innovation policy, with a five-year, €100 million[40] program launched in 2006 called "SERVE—Innovative Services Technology Programme."[41] Finland's neighbors soon followed suit, recognizing the increasing importance of services as their domestic manufacturing industries departed for cheaper production centers abroad, particularly in the form of "near-shoring" to Baltic and Eastern European countries. The same phenomenon affected developed Pacific Rim countries, as manufacturing moved first from Japan and Taiwan to cheaper production centers in China, and now out of China and on to the poorer nations of Southeast Asia. This process has forced almost all industrialized countries to seek to migrate their economies up the value chain towards knowledge-based, high-value-added services activities such as R&D, design, finance, consulting/training, and post-installation service and support.

Policy approaches quickly evolved into two main strands. First, these countries strove to develop framework conditions that support competitive services industries. As they began to scrutinize their services industries, these countries found they first needed considerable work in setting favorable framework conditions, such as removing barriers to labor market mobility in services industries, further opening and integrating cross-border services markets, developing better accounting practices for intangible assets, updating intellectual property and trade laws to accommodate the unique characteristics of services, developing core information technology infrastructure, and providing structures and incentives to encourage services exports.

Second, with this supportive policy framework in place, these countries implemented specific programs to support innovation in services businesses. Specific efforts (and at least one sample country implementing them) include:[42]

- Boosting academic research in the area of services innovation and services business, especially research on creating innovative services-based business models, quantifying improvements in services productivity, and enhancing the quality of services delivery. (Finland, The Netherlands, Denmark)
- Funding Services Science research; that is, cross-disciplinary research that draws on fields such as computer science, management, operations, marketing and organizational behavior. (Singapore, Taiwan)
- Extending research and experimentation tax credits to services industries; especially, defining where the "innovative step" occurs for services firms. (Norway and The Netherlands)
- Developing innovation metrics that measure innovation in services, not just advanced manufacturing, and looking for "hidden innovation" in services industries. (Great Britain, the United States, Ireland)
- Supporting the development of creative industries through establishing regional design centers. (South Korea, the Netherlands, Great Britain)
- Providing online self-assessment tools that allow companies to benchmark their innovation infrastructures (R&D budgets, number of employees, intellectual property strategies) against in-nation and in-industry peer companies. (Great Britain and European Union)
- Benchmarking services innovation policies across European countries. (European Union)

3. Tax Incentives for Research and Development

The tax incentives the U.S. government provides corporations for R&D activities have fallen from the most generous in the world in the late 1980s to 17th among 30 OECD countries in 2004.[43] Many nations now provide significantly more generous tax incentives for research than does the United States. From leading the world in the late 1980s,[44] the United States by 1996 fell to seventh most generous among OECD nations, behind Spain, Australia, Canada, Denmark, the Netherlands and France.[45] By 2004, we had fallen to 17th in generosity for general R&D; 16th for machinery and equipment used for research; and 22nd for buildings used for research.[46]

Among nations with a tax incentive for R&D, the United States now provides one of the weakest incentives, below our neighbors Canada and Mexico, and behind

many Asian and European nations. Japan's credit is almost three times as generous as the United States', and for small companies it's four times as generous. In 2004, France adopted a credit essentially equivalent to a 40 percent incremental R&D tax credit. In an explicit effort to attract U.S. corporate R&D, our neighbor to the north is even more generous. In Canada, large companies are eligible for a flat 20 percent credit while small companies can receive a 35 percent credit; in many provinces, equally generous credits can be taken on top of the Federal credit. Indeed, over the past decade, all other nations with R&D tax incentives have boosted the generosity of their R&D tax incentives, particularly since 2000.[47]

At a time of increased concern about America's growing competitiveness challenge, our tax credit has been getting weaker, both in absolute terms and relative to other nations, in part because of changes made by Congress over the years that have diminished its generosity.[48] In fact, until the passage in 2006 of the Alternative Simplified Credit, the credit was about half as generous as it was in the early 1980s.[49] Even with the recent increases in R&D tax incentives (the passage of the Alternative Simplified Credit in 2006 and its expansion in the Emergency Economic Stabilization Act of 2008), the United States moved up only to 14th place. Out of the 21 OECD nations that offered R&D tax credits in 2008, the United States ranked 17th. The United States would need to increase the ACS to 20 percent to move up to 10th place, 31 percent to move to 5th place, and 47 percent to become the most generous of the OECD nations.[50] However, this doesn't include non-OECD nations such as India, China and Brazil, all of which have significantly more generous tax incentives to attract multinational R&D. India's R&D tax credit is now four times that of the United States. On top of salaries for R&D personnel that are as low as one-sixth of the costs in the United States, China provides a 150 percent deduction on R&D expenses (provided that R&D spending increased ten percent over the prior year). Some countries, including Denmark and the Netherlands, have begun to extend R&D tax credits to cover process R&D activities, effectively extending the R&D tax credit from their goods to services industries as well.

4. High-Skill Immigration

Over the last decade, many nations have liberalized their policies regarding high-skill immigration, while the United States, in stark contrast, has restricted its policies. In a study benchmarking high-skill immigration policies in eight nations (the United States, Canada, New Zealand, Australia, Japan, Great Britain, Germany and France), "Global Flows of Talent: Benchmarking the United States," ITIF found that the United States trails other peer countries in developing a proactive approach to attract high-skill foreign workers.[51]

Using data from 2001 to 2006, the United States received an average of about 67,000 highly skilled permanent immigrants per year, with Canada receiving 56,000 per year, Australia 20,000 and New Zealand about 10,000.[52] As a share of their populations, these rates are all several times larger than those in the United States—more than 11 times larger in the case of New Zealand.

ITIF's study of the immigration policies of those eight countries found three broad approaches. The first group—Australia, Canada and New Zealand-conceive of immigrants as a source of economic growth and consider highly skilled immigrants especially valuable contributors. The second group-the United States and Great Britain—are more amenable towards immigration but do not place high priority on tilting the mix of immigrants toward the talented. The third group—France, Germany and Japan—tend to view highly skilled immigrants (and immigrants in general) more as threats to native workers than as positive additions to national well-being.

While the United States may not be as reflexively anti-immigration as some other industrialized countries, in recent years it has severely limited the flow of foreign talent entering the country at a time when the science and engineering workforce in the United States has become increasingly reliant on foreign talent. In 1995, non-U.S. citizens accounted for only six percent of the U.S. science and engineering workforce; by 2006, that percentage had doubled to 12 percent, and for the youngest cohort of scientists and engineers (ages 21 to 35), the percentage rose to 20 percent.

With the United States restricting the number of H–1B visas issued annually to 85,000 from 2006 to 2008 (and 65,000 as of today),[53] almost 50 percent of highly talented foreign professionals who applied for temporary work in the United States in the years 2006 to 2008 were turned away. Limiting the influx of talented foreign-born science and engineering professionals not only hurts U.S. competitiveness, it may also contribute to the decision of companies to source R&D operations abroad to be closer to local pools of S&E talent.

Why Does the United States Need a Robust Innovation Policy?

The global competitive landscape continues to stiffen as a number of countries get serious about creating favorable climates that attract foreign direct investment and R&D activities and that support the innovation efforts of their domestic corporations and workforce. It is time for the United States to articulate and implement an innovation-led economic growth strategy to respond to global economic competitiveness challenges.

But before detailing some of the key elements of such a strategy, it is first worth briefly discussing why there is a need to develop such a strategy. Unfortunately in the United States too many conventional "neoclassicalist" economists hold on to the antiquated view that economic welfare is maximized by individual firms acting as independent utility maximizers, doing what is best for them individually. In fact, according to this view, many policy efforts to help firms become more innovative will only make things worse. Indeed, the worst possible sin in the eyes of neoclassical economists is to "pick winners and losers" (an absurd characterization since nations only pick winners, not losers). Substituting for the wisdom of the market can only lead to a worse, not better, allocation of resources, they opine.

Because of that, many conventional neoclassical economists argue that policy makers should be indifferent to the occupational and industrial mix of the U.S. economy. For most neoclassical economists, the right industrial structure is the one that "the market" provides, because by definition market exchanges engaged in by two parties are what is known as "Pareto optimal." Why else would the parties engage in them? Any attempt by policy makers to try to alter this invisible hand by increasing innovation output can only reduce, not increase, economic welfare. This view, it should be noted, is almost unique in the world. In no other nation, perhaps with the exception of British Commonwealth nations, does the economics profession consist of such a large cohort of neoclassicalists counseling such blind faith in market processes.

This helps explain a key reason why so many neoclassical economists advising Washington have been so blase about the decline in U.S. high-tech manufacturing. To the extent that they are even willing to admit that high-tech manufacturing has declined, they simply assert as a matter of faith that domestic resources left idle by offshoring will automatically shift to new higher-productivity industries. The magic of the market will optimally reallocate resources. But only if one believes that economies are largely made up of "Coasian" factors of production that assemble and reassemble on the basis of prices could one take this view seriously. As innovation economist Greg Tassey argues, "The central failure of current economic growth models is the assumption that shifts in relative prices will automatically elicit a Schumpeterian-type efficient reaction from domestic private markets—namely an adjustment involving development and assimilations of new technologies to replace offshored ones." [54]

According to this view, if a high-wage, high-tech firm like Boeing, for example, were to go out of business because of unfair European Commission subsidies to Airbus, as long as America maintains flexible labor and capital markets, these resources will flow into other industries, including into expanding or new firms and sectors. In such a market environment, policies are needed only to facilitate the transition of resources from losing to winning companies, including making sure that losing companies are not protected from this tough but necessary discipline, and helping workers get reemployed quickly. As a result, proponents of this view believe that as long as we have a good education system and don't restrain creative destruction, then all should be well.

This conventional view may have accurately described a country's economy before the emergence of the globalization era over the last two decades. During the old economy era, if firms could not compete and went out of business, the only issue was making sure that their assets, including employees, were quickly redeployed to other companies that could compete successfully. If Boeing failed, Northrop Grumman or Lockheed Martin would add capacity.

But in the new global economy, in which knowledge is increasingly the major factor of production, this framework no longer sufficiently explains industrial and economic change. As such, in the 21st century global economy, nations can no longer be indifferent to the industrial and value-added mix of their economy. In contrast to the neoclassical view, knowledge is not a free-flowing commodity held solely by individuals. It is embedded in organizations and if organizations die so too does a significant amount of knowledge. Moreover, there are significant spillover effects from firm activities and significant first-mover advantages, including learning effects that enable firms' early leads to translate into dominant positions. There are also significant network effects that mean that advancement in one industry (e.g., broadband telecommunications) can lead to advancement in a host of others (e.g.,

Internet video). As a result, for many parts of the U.S. economy exposed to international competition, if you lose it, you can't easily reuse it. In these cases, foreign high-value imports may end up substituting for the defunct U.S. product.

To bring this back to a company like Boeing, if America were to lose Boeing, in all likelihood it could not rely on market forces, even a dramatic drop in the dollar, to later recreate a domestic civilian aviation industry. For to do so would require recreating not just the firm, but it's complex web of suppliers, professional associations, university programs in aviation engineering and other knowledge-sharing organizations.

Clearly if Boeing were to go out of business, the economy would quickly regain "equilibrium" as factors of production were reabsorbed. But neoclassical economics assume that there is only one equilibrium and it is the role of government to make sure that that the market attains it. But new research suggests that there may be multiple equilibria in an economy, some better than others. Indeed, while economies can attain equilibrium, absent a robust innovation policy that equilibrium may not be a high-wage, high-skill equilibrium. Research by economist Elvio Accinelli has shown that there is strategic complementarily between the percentage of high-skill workers and high-value added, innovative firms in an economy. He finds that economies can be in perfect neoclassical equilibrium at either a high level of innovation or in a "poverty trap" of low skills and underinvestment in innovation. Since the poverty trap can be avoided if the number of innovative firms in an economy exceeds a threshold level leading to an increased number of skilled workers, there is a role for public policy to move economies to a high-level equilibrium on innovation.[55]

But there is a second reason for an innovation policy and that is because economies are subject to a host of "market failures" with the implication that markets acting alone will not always lead to optimal performance. Following are five market failures that cause markets to perform suboptimally:

1. Because individual firms cannot capture all the benefits of their own innovative activity, firms will produce less innovation activity than society needs. The first market failure has to do with who benefits from private companies' investments in innovation. The knowledge needed to create new products, processes and organizational forms is not something that can be completely contained within an individual firm. It inevitably spills over to other firms, which can use it without paying the costs of creating it. For example, an entrepreneur develops a new business model that others copy. A university transfers discoveries from the lab to the marketplace. A company makes a breakthrough that forms the basis of innovations that other companies can use. This is why studies have found that the rates of return to society from corporate R&D and investments in IT are at least twice the estimated returns that the company itself receives.[56] Firms' inability to capture all the benefits of their own innovative activity means that firms, left on their own, will produce less innovation than society needs.

2. R&D increasingly depends on collaboration between firms and universities but the interests of the collaborators are not well-aligned. Problems with the important interactions of firms and universities represent another area of possible market failure. As short-term competitive pressures make it difficult for even the largest firms to support basic research and even much applied research, firms are relying more on university-based research and industry-university collaborations. Yet, the divergent needs of firms and universities can hinder the coordination of R&D between these two types of institutions. University researchers are not necessarily motivated to work on problems that are relevant to commercial needs. University technology transfer offices do not always promote the licensing of university intellectual property to firms. Conversely, individual businesses sometimes want to "rent" universities' research capabilities and appropriate the resulting research discoveries for themselves. This can impede the free flow of knowledge that can contribute to innovation elsewhere in the economy.[57]

3. Many industries and firms lag in adopting proven technologies. Market failures also plague the diffusion of innovation. Outside of relatively new, science-based industries such as information technology and biotechnology, many industries lag in adopting more productive technologies. For example, the health care industry has lagged in adoption of available technologies that could boost productivity and health care quality.[58] The residential real estate industry has resisted moving toward more Internet-enabled sales.[59] The construction industry is plagued by inefficiencies and failure to adopt best-practice technologies and techniques.[60] A host of market failures, including chicken-or-egg issues related to standards and technology adoption and principal-agent problems where innovation may hurt the implementers of it (e.g., real estate agents embracing e-realty systems) impede faster productivity growth in these sectors of the economy.

4. The innovation producing benefits of industry clusters are under-realized. A fourth market failure involves the under-recognition of industry clusters' role in innovation. Both the creation and the diffusion of innovation often occur in geographic clusters. Geographic industry clustering enables firms to take advantage of common resources (e.g., a workforce trained in particular skills, technical institutes or a common supplier base), to facilitate better labor market matching and to facilitate the sharing of knowledge. This process may be particularly relevant in industries that rely more on the creation or use of new knowledge, as clustering appears to spur knowledge transfers. Such industries are especially likely to cluster in large metropolitan areas.[61] Perhaps the best known cluster is Northern California's Silicon Valley, where a large agglomeration of high-tech firms, research universities such as Stanford, technical colleges to train high-tech workers, venture capitalists, and other supporting institutions make it the world's most vibrant technology region. But Silicon Valley is not the only region in the United States with industry clusters: From the furniture cluster in Tupelo, Mississippi; to the jewelry cluster in Rhode Island and southern Massachusetts; to the recreational vehicle cluster in Elkhart, Indiana; to the biotechnology clusters in the Boston, Washington, DC, and San Diego metropolitan areas, regional industry clusters abound. And as these examples show, clusters are not only made up of "high-tech" firms. Moreover, clusters are not confined to manufacturing, but also exist in a host of service industries, including financial services in New York, movies and music in Hollywood, software in Seattle and gaming in Las Vegas. Evidence suggests that industry clustering may have become more important for productivity growth during the last three decades; the extent to which an industry was geographically concentrated (at the metropolitan or county level) was increasingly associated with subsequent productivity growth during the last three business cycles.[62]

Yet because the benefits of geographic clustering spill over beyond the boundaries of the firm, market forces produce less geographic clustering than society needs. Each firm in a cluster confers benefits on other firms in the cluster, but no individual firm takes these "external" benefits it produces into account when making its own location decisions. In addition, the firms in a cluster have common needs (e.g., for worker training or infrastructure) that they cannot meet on their own. Clustered firms usually require external coordination (e.g., from governments or industry associations) to meet these needs because no one firm can capture all the benefits. Failure to meet these common needs makes clusters smaller and less productive than they would otherwise be. If the benefits of clustering to all firms in the United States were considered and the common needs of all firms in each cluster met, there would be more clustering, and thus more innovation and higher productivity.

5. The interests of geographically mobile firms in locating innovative activity may diverge from those of U.S. residents. There is one other failure that has emerged in the last decade or so and that, while not a market failure per se, results in too little innovation in the United States. That failure is the potential divergence between the interests of geographically mobile firms and those of the residents of the United States.[63] Firms' decisions about where to locate innovative activity are based on their own interests, which may or may not coincide with the interests of a place's residents. Since World War II and the emergence of a truly national market, most U.S. states have put in place policies to tilt the choice of corporations to invest in their states. To be sure, even the most liberal governors recognize and respect the power and primacy of markets as the key driver of prosperity. But even the most conservative governors recognize that this market-produced bounty does not always automatically end up in their own jurisdiction. For this reason, both Republican and Democratic governors "intervene" in their economies with robust economic development policies. They are not content to let the "market" determine what kind and how many jobs are created: they work to ensure that they gain more high-paying, high-productivity jobs. With the rise of the globally integrated enterprise, the United States faces the same reality states faced after World War II: without robust economic and innovation policies, it risks losing out in global competition.

These failures in the process of innovation and its diffusion suggest that, left to itself, the market will produce less innovation and lower productivity in the United States than our society needs. In a globally competitive world, this is a limitation that we can no longer afford. What is more, these market failures in turn suggest that there are several ways in which government can improve the process.

What Steps Should Congress Take to Boost U.S. Innovation and Competitiveness?

The government's role in addressing these market failures is not to regulate business or to direct the path of technological or economic development. We do not advocate a heavy-handed, government-driven industrial policy. Indeed, such a policy cannot be nimble enough to respond to the kinds of market failures that afflict the innovation process. At the same time, though, we do not advocate giving away public funds to companies without any public benefit. Government should be a facilitator that spurs firms to innovate in ways that serve the public interest. Economist Dani Rodrik captures this view of the appropriate relationship between government and business with respect to innovation policy when he describes "an interactive process of strategic cooperation between the public and private sectors which, on the one hand, serves to elicit information on business opportunities and constraints and, on. the other hand, generates policy initiatives in response."[64] Political scientist Dan Breznitz similarly writes that a government innovation-promotion agency should not pick strategic products or technologies but should motivate firms, individually and in cooperation with other firms and government, to make the investments needed to innovate.[65] In short, while we believe that the private sector should lead in innovation, we also believe that in an era of globalized innovation and intensely competitive markets the Federal Government can and should play an important enabling role in supporting private sector innovation efforts. Indeed, many nations have already come to this realization. In recent years, they have come to understand that markets relying on price signals alone will not always be as effective as smart public-private partnerships in spurring higher productivity and greater innovation. It is time for the United States to do the same. There are two major areas where the United States needs to act, one domestic and one international.

More Robust Trade Enforcement

It will be difficult for the United States to regain global innovation leadership if we continue to largely turn a blind eye to rampant foreign policies that distort the spirit, if not often the letter, of the WTO, with the goal of limiting U.S. imports of high tech products and services and promoting their exports. These countries want it both ways. They desperately want access to the U.S. market (and as reflected by the fact that the United States has run massive annual trade deficits, for instance, of almost $800 billion in 2006 alone,[66] they are getting it) but they don't want to buy U.S.-produced goods and services. They want U.S. foreign direct investment, particularly high-tech investment, through outsourcing, joint ventures and other types of investment, but they also want to systematically weaken the competitive advantage of U.S. technology companies in favor of their domestic technology companies. They want our wonderful technology and intellectual property, but they don't want to pay for it. "Take" is not "trade."

These aggressive technology mercantilist policies have resulted in fewer high paying technology jobs in the United States and have eroded the United States' global innovation leadership position. As such if we want to stop the continued erosion of America's technology leadership, the Federal Government will have to be much more vigilant and make fighting these unfair trade practices a top priority. Both Congress and the Obama Administration need to let countries know that they can't expect to get the WTO's benefits when they aren't meeting its obligations. Countries are willfully violating these agreements and we need to make them live up to their commitments.

While many of the tools for more aggressive enforcement of global trade policies are in the hands of the administration, Congress can play an important supporting role. To start with, we urge Congress to pass S.1466: The Trade Enforcement Act of 2009, which strengthens USTR's trade enforcement powers and restructures the agency to more greatly focus on eliminating foreign barriers to exports.[67] In short, Congress should hold USTR's feet to the fire and expect them to wake up every morning figuring out how they are going to enforce trade agreements, and defend American technology jobs from the assault of unfair trade practices.

Develop and Implement a More Robust National Innovation Policy

Even with the orientation of many neoclassical economists there is a somewhat broad consensus that the role of the Federal Government should include support for basic research, education, and provision of a good regulatory climate. But while these are necessary ingredients, they are woefully inadequate in enabling the United States to increase its global rank in innovation-based competitiveness. Indeed the neoclassical model which not only posits an overly simplistic innovation process (the linear model) but also assumes that it is only basic research which re-

quires a government role is a poor guide to policy. Generic platform technologies, infra-technologies and risk reduction all also require a public-private approach. What are essentially ideological statements put forth by neoclassical economists, such as that the role of government is not to support applied research, are supported by little logic and even less data and only serve to stop, not advance, needed reasoned analysis and discussion. With this in mind, I list a number of specific proposals that if enacted would help the U.S. regain its innovation lead.

1. Spur Science, Technology, Engineering and Math (STEM) Education and Skills

Ensuring an adequate supply of talented scientists and engineers is one key step in the U.S. innovation agenda. Following are three proposals to address the STEM challenge:

1a) Fund Specialty Math and Science High Schools

A wide array of proposals before Congress seek to intervene upstream in the STEM pipeline at the K–12 level. These include expanding professional development programs for science teachers; enhancing science enrichment programs; using No Child Left Behind to judge scientific educational outcomes; and boosting science teacher quality, either through stricter requirements, providing incentives to attract higher quality teachers to science, and/or making it easier for scientists and engineers to become teachers.

While these proposals have received the lion's share of attention in the policy debates over STEM education, we believe that the focus is too broad. If funding were unlimited, such a broad-based strategy might make sense. But since funding is limited and since less than ten percent of the U.S. workforce is engaged in STEM-related careers, it makes more sense to focus limited funds more narrowly. In particular, we believe that the most effective strategy to address the STEM challenge at the high school level is to significantly expand the number of specialty math and science high schools (MSHS).

There are only about 100 math and science high schools across the nation, ranging from pull-out programs with 125 students, to full day programs and dedicated high schools of over 4,000 students, to state sponsored residential schools, enrolling over 47,000 students in total.[68] By creating an environment focused more intensely on science and technology, these schools have been able to successfully enable students to study science and math, often at levels far beyond what students in conventional high schools are at; they can then go on to degrees in math and science at relatively high levels. It's time to build upon this successful model and significantly expand the number and scope of our nation's math and science specialty high schools.

Mathematics, science, and technology high schools differ from the general education found in comprehensive high schools in key ways. First, as the name implies, MSHSs focus much more extensively on STEM curricula. For example, in addition to the three years of lab science and three years of mathematics required by the state for high school graduation, Florida's Center for Advanced Technologies offers students an opportunity to declare a mathematics and science major by taking four additional courses in mathematics and science, often Advanced Placement Courses.[69]

Second, students don't just take more STEM courses; they take more advanced courses and do more advanced work. Indeed, the coursework and integrated curricula of MSHSs go over and above the normal graduation requirements for general education students. For example, students at the Arkansas School for Mathematics, Sciences, and the Arts can take courses in Biomedical Physics, Immunology, Microbiology, Multivariable Calculus, Number Theory, Differential Equations, Math Modeling, Computer Programming III, and Web Application Development.

A third distinguishing feature of these schools is their level of partnership with other organizations. Collegiate, corporate, and alumni organizations have formed significant partnerships with these schools. While some partnerships have been in support of specific events, others have been long-term partnerships supporting research and innovation among students and faculty. Collegiate partners, for example, often provide classroom, dormitory, research and financial support to these schools. For example, at the Governor's School of South Carolina, every rising senior is placed for six weeks in the summer at an off-campus program. Many of the students work with a research professor at an in-state university.

While the educational environments are exemplary, the key question is whether they produce results. While formal studies are few, there is some evidence that these schools are highly effective at producing graduates not only with high levels of aptitude in STEM, but who go on to further study and careers in STEM. For ex-

ample, one study of 1,032 graduates finds, 99 percent of graduates enroll in college within one year of high school (compared to 66 percent nationally) while 79 percent complete college in four years (compared to 65 percent in private universities and 38 percent in public universities).[70] Moreover, graduates earn undergraduate and graduate degrees in mathematics, science, and technology fields in significantly higher numbers than the general population. Approximately 56 percent of MSHS graduates earn undergraduate degrees in mathematics or science-related fields, compared to just over 20 percent of students who earn an undergraduate degree. Over 40 percent of females earn such degrees, nearly double the national average.

A key part of any solution to the STEM challenge needs to be the significant expansion of specialty math and science high schools. But because more so than other high schools, math and science high schools produce benefits that local communities, and even states, will not capture, local school districts will under-invest in them. Rather than be seen as solely the responsibility of local school districts, or even states, they should be seen for what they are: a critical part of the scientific and technological infrastructure of the nation. Thus, we believe that the National Science Foundation should play a key role in supporting and expanding such schools. As a result, **Congress should set a goal of approximately quintupling enrollment at such high schools to around 250,000 students. This will require both the creation of a significant number of new high schools, but also expansion of others with room to grow. To do this, Congress should allocate $100 million a year for the next five years to the National Science Foundation to be matched with funding from states and local school districts and industry to invest in both the creation of new MSHSs and the expansion of existing ones.[71]** Moreover, a share of these funds should go toward establishing MSHSs focused on under-represented populations. States and/or local school districts would be required to match every dollar of Federal support with two dollars of state and local funding. Industry funding would count toward the state and/or local school district match.

1b) Fund Joint Government-Industry STEM Ph.D. Fellowships

One key factor in producing more Ph.D. degrees in STEM, especially by U.S. residents, is the ability to support doctoral fellowships. But as Richard Freeman notes, the number of NSF graduate research fellowships awarded per thousand of college students graduating with degrees in science and engineering went from over seven in the early 1960s to just over two in 2005. Today the same number of NSF graduate research fellowships are offered per year as in the early 1960s, despite the fact that the number of college students graduating with degrees in science and engineering has tripled.[72] But rather than simply expand funding for the NSF Graduate Research Fellowship program (funded at $102 million) to do this, Congress should instead create a new NSF-industry Ph.D. fellows program. Currently the program provides up to three years of support over a five year period and supports approximately 3,400 students per year at $40,500 per year.[73] The new NSF-industry program would work by enabling industry to fund individual fellowships of $20,250 with NSF to match industry funds dollar-for-dollar. **Congress should allocate an additional $21 million to a joint industry-NSF STEM Ph.D. fellowship program.** This would allow NSF to support an additional 1,000 graduate fellows.

Individual companies could commit to supporting American residents in whatever fields that the companies are interested in. Students would of course be under the supervision of their university faculty, and ultimately dissertation advisor, but industry would be able to build a relationship with the student. For example, a company might offer the student a summer internship at one of the company's laboratories, helping the student to get a better sense of actual research challenges the company faces.

To be sure, this program would be slightly more complicated to administer. First, companies would have to be informed of the program and propose graduate fellow areas of study. Prospective fellowship applicants would have to identify which awards they are most interested in applying for. However, with the Internet, such matching would be relatively straightforward, with students indicating their intended areas of study and the online program identifying relevant fellowship opportunities. If after three years, it turns out that industry does not support the program in great enough numbers or students and universities are not interested in the program, then it could and should be terminated and the funding redirected into the regular fellows program.

However, this program would have two advantages over the regular NSF fellows program. First, by leveraging industry funds, Federal dollars would go twice as far. Instead of having to appropriate $42 million to fund 1,000 additional fellowships, they could appropriate $22 million instead. Second, and more important, engaging

industry as a partner would help selected graduate students better understand how research is conducted in industry and better understand the interdisciplinary nature of today's innovation process. Both of these challenges have been the subject of increasing focus by scholars writing about STEM graduate education. There have been several studies about the growing disconnect between the training that graduate students receive and their future job responsibilities.[74] Most doctoral programs still train students as if they were going to be going into academic teaching and research careers. But increasingly this is not the case.[75] For example, one survey of doctoral chemistry students found that only 36 percent intended to go into academia (compared to 76 percent of English students).[76] As Campbell, Fuller and Patrick have argued, "graduate education needs to be broadened from its research focus to include a wider range of training for the careers students are pursuing and to reflect the versatility needed to work in an increasingly global job market, where collaboration between industry, universities, and government agencies is the norm rather than the exception."[77] Finally, for those who worry that industry funding will somehow taint the scientific learning process, it is important to remember that students would be guaranteed the funds as long as the university agreed that the student was performing up to standards.[78]

1c) Allow Foreign Students Receiving STEM Ph.D.s from U.S. Universities to Automatically Qualify for Green Cards

While ideally the supply of American STEM workers will expand to fill the gap, the likelihood of that happening in the near- to moderate-term is unlikely, even if Federal efforts to support STEM education expand significantly. Yet welcoming the world's most skilled foreign-born scientists and engineers into the land of economic opportunity that America affords has long been one of the strengths of the U.S. national innovation system. The U.S. economy and the standard of living for American citizens have benefited enormously from this influx of foreign talent. AnnaLee Saxenian, a professor at the University of California-Berkeley, has shown that Indian and Chinese entrepreneurs founded or co-founded roughly 30 percent of all Silicon Valley startups in the late 1990s.[79]

Recognizing this, over the last decade many nations have liberalized their policies regarding high-skill immigration, while the United States, in stark contrast, has restricted its policies. In a study benchmarking high-skill immigration policies in eight nations (the United States, Canada, New Zealand, Australia, Japan, Great Britain, Germany and France), ITIF found that the United States trails other peer countries in developing a proactive approach to attracting high-skilled foreign workers.[80]

Moreover, the current system of employer sponsorship signals only that potential immigrants are desirable employees. A system that allowed additional criteria to be considered, like those used in the point systems of Australia, Canada and New Zealand, would meet policy objectives better. (Applicants for immigration in these countries receive points for such characteristics as education, work experience and language skills. Those surpassing an adjustable point threshold are admitted. Having a job offer in hand and meeting a designated occupational shortage may add points to an individual's application, but it is usually possible to meet the pass mark without either of these attributes.) Toward that end, foreign graduate students in STEM fields should be given special preference within such a system, even if they have not received job offers. To do this, **Congress should automatically make recipients of advanced science and engineering degrees eligible for permanent residency.** Providing additional opportunities for green cards not tied to employment could allow highly skilled foreign graduates to make more creative contributions to the economy more quickly by working in smaller and riskier businesses.

2. Create a National Innovation and Competitiveness Strategy Modeled on the National Broadband Strategy

The United States needs to create millions of new good-paying jobs over the next decade. If the United States wants to do this and be successful in the global economy, it is critical that the Federal Government develop a serious, in-depth, and analytically-based national competitiveness strategy. We are in fact one of the few nations without one. Denmark, the United Kingdom, South Korea, The Netherlands and Ireland are just a few of the nations that in recent years spent the time and effort to craft a national competitiveness strategy. The last time the United States did anything similar was President Carter's Domestic Policy Review on Industrial Innovation in 1978. This review was in fact extremely important in setting the stage for a number of important Congressional initiatives in the following decade, including the R&D tax credit, the Bayh-Dole Act, the National Cooperative R&D Act, and the Stevenson-Wydler Technology Innovation Act.

It should be noted that ITIF is not advocating industrial policy or top-down direction of innovation. Thus we have deliberately chosen the term "agenda" to describe the outcome of a process that we believe must engage private and civil society constituencies and reflect the bottom up as well as top down nature of innovation. This would allow the development of a robust national innovation agenda. Its value would be apparent in allowing our country to more effectively address complex challenges with "whole of government" solutions, galvanize the public by advancing a useful narrative around innovation, enable us to engage more effectively with global innovation constituencies, and most importantly allow us to reinvent the traditional sources of our economic and societal success.

The American Recovery and Reinvestment Act charged the FCC with the development of a national broadband plan. The next *America COMPETES Act* should charge the White House Office of Science and Technology Policy with the development of a national competitiveness strategy. Adequate funding should be provided to bring in an outside director with deep technical and policy knowledge and hire individuals with technical and business experience.

A national innovation strategy would provide an opportunity to engage in a comprehensive analysis of the key factors contributing to future U.S. competiveness. Legislation to create this could require that the strategy focus on a number of broad issues, going more in depth on each. These should include assessing: 1) current U.S. competitiveness, including at the major industry level; 2) current business climate for competiveness (including tax and regulatory); 3) trade and trade policy issues; 4) education and training; 5) science and technology policy; 6) regional issues in competitiveness (including the role of state and local government and impacts on rural, urban and other regions); 7) measurement and data issues; and 8) proper organization of government to support a comprehensive innovation and competitiveness agenda.

3. Spur Technology Commercialization

While the United States remains a leader at nurturing innovation and commercializing new inventions, the process can and should be improved. The United States will forfeit technology leadership unless it finds ways to accelerate entry of new growth sectors. The U.S. innovation system separates fundamental research from incremental development, with the former increasingly performed at research universities and labs with Federal support, and the latter performed by industry. Connections between these sectors need significant strengthening, so there is a smoother and more active hand-off process. Recommendations include:

3a) Create an SCNR (Spurring Commercialization of Our Nation's Research) Program to Support University, State and Federal Laboratory Technology Commercialization Initiatives

The current Federal system for funding research pays too little attention to the commercialization of technology, and is still based on the linear model of research that assumes that basic research gets easily translated into commercial activity. In fact, the process is ripe with barriers, including institutional inertia, coordination and communication challenges, and lack of funding for proof of concept research and other "valley of death" activities. It is time for Federal policy to explicitly address this challenge and allocate more funding to commercialization activities.

However, in an era of fiscal constraint adequate new funding may be difficult to obtain. As a result, one idea would be to establish an automatic set-aside program taking a modest percentage of Federal research budgets and allocating them to a technology commercialization fund. Currently the SBIR program allocates 2.5 percent of agency research budgets to small business research projects; the STTR program allocates 0.3 percent to universities or nonprofit research institutions that work in partnership with small businesses.

3b) Thus, Congress should allocate 0.15 percent of agency research budgets (around 5110 million per year) to fund university, Federal laboratory, and state government technology commercialization and innovation efforts. The 0.15 percent share could either be added on top of the existing 2.8 percent allocation currently going to SBIR and STTR, or it could be taken from the SBIR share.

This program would be different than the STTR program which funds small businesses working with universities.[81] Half the funds would go to universities, and Federal laboratories could use the funds to create a variety of different initiatives, including mentoring programs for researcher entrepreneurs, student entrepreneurship clubs and entrepreneurship curriculum, industry outreach programs, seed grants for researchers to develop commercialization plans, etc.

The other half of funds would go to match state technology-based economic development (TBED) programs. Since the 1980s, when the United States first began to face global competitiveness challenges, all states have established TBED programs. Republican and Democratic governors and legislators support these programs because they recognize that businesses will not always create enough high-productivity jobs in their states without government support. State and local governments now invest about $1.9 billion per year in TBED activities.[82] This is about 70 percent of the amount that the Federal Government spends on its principal innovation programs and agencies.

States and regions engage in a variety of different TBED activities. They spur the development of cutting-edge, science-based industries by boosting research funding. For example, Oregon's NanoScience and Microtechnologies Institute serves as a forum for R&D synergy among Oregon's three public research universities, the Pacific Northwest National Laboratory, the state, and the "Silicon Forest" high technology industry cluster. States also try to ensure that research is commercialized and good jobs created in both cutting-edge, science-based industries and industries engaging in related diversification. For example, the Georgia Advanced Technology Development Center at Georgia Tech is a technology incubator that offers services including consulting, connections to university researchers and networking with other entrepreneurs and service providers. States have also established programs to help small and mid-sized firms support collaborative research at universities. For example, Maryland's Industrial Partnerships program provides funding, matched by participating companies, for university-based research projects that help companies develop new products or solve technical challenges.[83] Finally, states have established initiatives to help firms commercialize research into new business opportunities. For example, Oklahoma's non-profit i2E organization helps Oklahoma companies with strategic planning assistance, networking opportunities, and access to capital. i2E's Oklahoma Technology Commercialization Center assists researchers, inventors, entrepreneurs and companies in turning advanced technologies and high-tech startups into growing companies.[84] But without assistance from the Federal Government, states will invest less in TBED activities than is in the national interest. A formula-based allocation to help fund state TBED efforts would help correct this limitation.

We propose that NIST be responsible for administering this program. Universities and Federal labs would submit proposals explaining their proposed activities. States would submit proposals to NIST laying out their TBED strategy and explaining how NIST support would enable them to do more and better. Qualifying activities would include a host of TBED activities, such as technology commercialization centers, industry-university research centers, regional cluster development programs, regional skills alliances, and entrepreneurial support programs. In addition, where relevant, states would need to spell out in detail how they intended to create innovation alliances among local governments, businesses, educational institutions, and other institutions (such as economic development organizations or labor unions) in metropolitan areas. States would have to explain how their activities would meet the needs of firms following innovation trajectories that currently exist or that can reasonably be developed within the state. The precise mix of TBED activities would be left up to each state because the mix of innovation trajectories and the specific needs of firms in each trajectory vary among and within states. However, proposals would have to be economically realistic. For example, a state proposal to develop a new biotechnology cluster in a metropolitan area that had no existing institutions to support such a cluster and no realistic strategy to develop those institutions would be unlikely to be funded. Proposals that built appropriately on TBED activities in neighboring states or that included plans for interstate collaboration in TBED would receive extra points in the review process. To be eligible for NIST funding, states would need to provide at least two dollars in actual funding for every NIST dollar they receive.

Rotating panels of TBED experts would review proposals. In most cases these would be experts in the field (e.g., consultants, academics, venture capitalists and economic development professionals). For states there would be a two-stage proposal review process. States would submit initial proposals describing activities and use of funds. Based on review from the TEED panel and NIST staff, the program would provide feedback to states on how to modify and improve their proposals. States would then submit final proposals that would be reviewed and scored by the outside panel of experts. Proposals that were judged acceptable would be funded to the extent that funds were available, with priority going to those with the highest scores. States with proposals judged not fundable would be eligible to receive modest planning grants and technical assistance from NIST staff to develop a proposal for the subsequent year's competition.[85]

4. Expand the R&D Tax Credit

As ITIF has demonstrated, the U.S. R&D tax credit is no longer generous when compared to other nations. It is not enough to make the credit permanent, it also needs to be expanded. There are several reforms that are needed. One is to provide greater incentives for collaborative R&D. Increasingly, firms are collaborating with other firms or institutions in order to lower the cost of research and increase its effectiveness by maximizing idea flow and creativity. Indeed, a growing share of research is now conducted not only on the basis of strategic alliances and partnerships but also through ongoing networks of learning and innovation.[86] Moreover, participation in research consortia has a positive impact on firms' own R&D expenditures and research productivity.[87]

Most collaborative research, whether in partnership with a university, national laboratory, or industry consortium, is more basic and exploratory than research typically conducted by a single company. Moreover, the research results are usually shared, often through scientific publications. As a result, firms are less able to capture the benefits of collaborative research, leading them to under-invest in such research relative to societally optimal levels.[88] This risk of underinvestment is particularly true as the economy has become more competitive, and a reflection of this is the fact that for the first time since the data were collected in 1953, the percentage of U.S. academic R&D supported by industry has declined in each of the last five years.[89] This may stem from the fact that university contracts are often undertaken as discretionary activities and are the first to be cut when revenues are down.[90]

Other countries, including France, Norway, Spain and the United Kingdom, provide firths more generous tax incentives for collaborative R&D. Denmark and Hungary provide more generous tax deductions for collaborative R&D with public research institutions.[91] Japan's R&D incentive is almost twice as generous for research expenditures companies make with universities and other research institutes.[92] France provides a 60 percent flat tax credit for business-funded research conducted at national laboratories.

The U.S. tax code allows firms a basic research credit of 20 percent of expenses above a base period amount.[93] But the credit is not significantly more generous than the regular credit. Moreover, its applicability is limited because rules require that such research not have any "specific commercial objective." At a minimum, **Congress should delete this restrictive language from current law and allow any research expenditures at universities to qualify for the basic research credit.**

But Congress should go further and provide a more generous incentive for collaborative research. As part of the Energy Policy Act of 2005, Congress created an energy research credit that allowed companies to claim a credit equal to 20 percent of the payments to qualified research consortia (consisting of five or more firms, universities, and Federal laboratories) for energy research. In 2006, several bills were proposed allowing all research consortia, not just energy-related ones, to become eligible for a 20 percent flat credit.[94] **Congress should go further and allow firms to take a flat credit of 30 percent for collaborative research conducted at universities, Federal laboratories, and research consortia.**

In addition, Congress needs to expand the Alternative Simplified Credit. Currently the ASC provides a credit of 14 percent of qualified R&D expenditures in excess of 50 percent of base period expenditures. **Congress should increase the Alternative Simplified Credit rate from 14 percent to between 20 and 40 percent, depending on the level of increase in research investment. Congress should also broaden the definition of qualified R&D from beyond that involved in inventing a new product, to that involved in developing a new production process.** Under current law only product R&D is eligible for the credit. But a key source of U.S. manufacturing renewal will come from more advanced production processes. Allowing companies to take a credit against process R&D investments would spur more of this kind of research. Taking these steps would put the U.S. R&D tax credit back among the top 5 most generous in the world.

5. Fund Industry-University-Government Manufacturing Research and Deployment Centers

The debate over science and technology policy has tended to oscillate between those who argue that the Federal Government should fund industry to conduct generic pre-competitive R&D and those who maintain that money should be spent on curiosity-directed basic research at universities. This is a false dichotomy. There is no reason why some share of university basic research cannot be oriented toward problems and technical areas that are more likely to have economic or social payoffs

to the nation. Science analyst Donald Stokes has described three kinds of research: purely basic research (work inspired by the quest for understanding, not by potential use), purely applied (work motivated only by potential use), and strategic research (research that is inspired both by potential use and fundamental understanding).[95] Moreover, there is widespread recognition in the research community that drawing a bright line between basic and applied research no longer makes sense. One way to improve the link between economic goals and scientific research is to encourage the formation of industry research alliances that fund collaborative research, often at universities.

While the government supports a few sector-based research programs, they are the exception rather than the rule.[96] Moreover, existing ones are largely underfunded. As a result, **Congress should fund a competitive Industry Research Alliance Challenge Grant program to match funding from consortia of businesses, businesses and universities, or businesses and national labs.** This program would resemble the current Technology Improvement Program (TIP) operated by NIST but would have an even greater focus on broad sectoral consortia and would allow large firms as well as small and mid-sized ones to participate. It could be housed in either NSF or NIST.

To be eligible for matching funding, firms would have to: form an industry-led research consortium of at least five firms, agree to develop a mid-term (three-to-ten year) technology roadmap that charts out generic science and technology needs that the firms share, and provide at least a dollar-for-dollar match of Federal funds. This initiative would increase the share of federally funded university and laboratory research that is commercially relevant. In so doing it would better adjust the balance between curiosity-directed research and research more directly related to societal needs.

6. Establish a National Innovation Foundation

If Congress wanted to go further, it could establish a National Innovation Foundation (NIF)—a new, nimble, lean, and collaborative entity devoted to supporting firms and other organizations in their innovative activities.[97] The goal of NIF would be straightforward: to help firms in the nonfarm American economy become more innovative and competitive. It would achieve this goal by assisting firms with such activities as joint industry-university research partnerships, technology transfer from laboratories to businesses, technology-based entrepreneurship, industrial modernization through adoption of best practice technologies and business practices, and incumbent worker training. By making innovation its mission, funding it adequately, and focusing on the full range of firms' innovation needs, NIF would be a natural next step in advancing the innovation agenda that Congress put in place when it passed the *America COMPETES Act.* A National Innovation Foundation would:

- Catalyze industry-university research partnerships through national sector research grants.
- Expand regional innovation-promotion through state-level grants to fund activities like technology commercialization and entrepreneurial support.
- Encourage technology adoption by assisting small and mid-sized firms in taking on existing processes and organizational forms that they do not currently use.
- Support regional industry clusters with grants for cluster development.
- Emphasize performance and accountability by measuring and researching innovation, productivity, and the value-added to firms from NIF assistance.
- Champion innovation to promote innovation policy within the Federal Government and serve as an expert resource on innovation to other agencies.

By doing these things, NIF would address quite robustly each of the major flaws that weaken current Federal U.S. innovation policy. We recognize that in the current fiscal climate it will be difficult for the Federal Government to launch major new investment initiatives, especially since strong political forces on either side of the aisle oppose raising taxes or cutting spending. Nevertheless, the compelling need to boost innovation and productivity merits a substantial investment in NIF. We propose that the Federal Government fund NIF at an initial level of $1 billion per year (with around $350 million coming from several programs that would be consolidated into NIF), ramping up to $2 billion after several years. At $2 billion, NIF's budget would be approximately one-third the size of NSF's. In addition, because of its strong leveraging requirements from the private sector and state gov-

ernments, NIF would indirectly be responsible for ensuring that states and firms spend at least one dollar on innovation for every dollar NIF spent.

7. Federal Institutional Reforms to Spur Innovation

Innovation policy is not just about tax incentives or funding for government programs. It is about a wide array of government actions that can have an impact on innovation. But currently, the institutional ability of the Federal Government to strategically and comprehensively spur innovation is more limited than it needs to be. To remedy that we propose two recommendations:

7a) Form an Office of Innovation Policy in OMB (i.e., an Office of Information and Regulatory Affairs for Innovation) [98]

The relative absence of innovation from the agenda of many relevant Federal agencies—as well as interagency processes such as the centralized cost-benefit review performed by the Office of Information and Regulatory Affairs (OIRA) within the Office of Management and Budget (OMB)—manifests the confluence of two regulatory challenges: first, the tendency of political actors to focus on short-term goals and consequences; and second, political actors' reluctance to threaten powerful incumbent actors. Courts, meanwhile, lack sufficient expertise and the ability to conduct the type of forward-looking policy planning that should be a hallmark of innovation policy.

7b) To remedy these problems, Congress should create a White House Office of Innovation Policy that would have the specific mission of being the "innovation champion" within these processes. OIP would be an entity that would be independent of existing Federal agencies and that would have more than mere hortatory influence. It would have some authority to push agencies to act in a manner that either affirmatively promoted innovation or achieved a particular regulatory objective in a manner least damaging to innovation. OIP would operate efficiently by drawing upon, and feeding into, existing interagency processes within OIRA and other relevant White House offices (e.g., the Office of Science and Technology Policy). It is important to note that OIP would not be designed to thwart Federal regulation; as a matter of fact, in some cases, the existence of OIP might lead to increased Federal regulation (e.g., more Environmental Protection Agency regulations might pass muster under cost-benefit analysis if innovation-related effects were calculated).

Some might question the significance of this proposal. Isn't creating an OIP a fairly small change to the system? Certainly adding OIP to the existing mix is a smaller change than jettisoning the existing substantive agencies in favor of a new agency with authority to regulate, and promote, innovation across all government agencies. But implementing this proposal will significantly change the regulatory environment. First, an entity focused on innovation would add an important new voice to the regulatory conversation. There would now be an entity speaking clearly and forthrightly on the centrality of innovation. Second, and more important, OIP would not merely have a voice: it would be able to remand agency actions that harm innovation. It would also have as part of its mission proposing regulation that benefits innovation. This is no small matter. Indeed, it would change the regulatory playing field overnight.

To those who might oppose an OIP on the grounds that making predictions about the future is very difficult and that experts are often wrong when they make such predictions, our response is straightforward: Agencies are already making predictions about the future (whether consciously or not) when they make laws that affect innovation. They are simply doing so in a manner that is unsystematic, haphazard, and subject to undue influence by well-funded incumbents. We can do better.

Conclusion

For over half a century, the United States led the world in innovation on a per-GDP and per-capita basis. This leadership role not only enabled America to be the leading military power, it enabled us to be the leading economic power, with the resultant economic and social benefits that came with that. But now more than ever, the American standard of living depends on innovation: To be sure, companies are the engines of innovation and the United States has an outstanding market environment to fuel those engines. Yet firms and markets do not operate in a vacuum. By themselves they do not produce the level of innovation and productivity that a perfectly functioning market would. Even indirect public support of innovation in the form of basic research funding, R&D tax credits, and a strong patenting system,

important as they are, are not enough to remedy the market failures from which the American innovation process suffers.

At a time when America's historic lead in innovation has evaporated and its relative innovation competitiveness continues to shrink, when more and more high-productivity industries are in play globally, and when other nations are using explicit public policies to foster innovation, the United States cannot afford to remain complacent. Relying solely on firms acting on their own will increasingly cause the United States to lose out in the global competition for high-value added technology and knowledge-intensive production. Congress has an opportunity to take steps now to stop and reverse this slide, but only if it adopts the kinds of policies and makes the kinds of investments needed to help firms in the—United States do a better job of driving innovation here at home.

Endnotes:

[1] Elhanan Helpman, *The Mystery of Economic Growth* (Cambridge, Massachusetts: Belknap Press, 2004).

[2] This is not to say that these nations have not developed some technology-based jobs. It is to say that relative to the rest of their economies, technology jobs will be a much smaller share than is the case in the United States. For an analysis of how, because of very low wages, China is specializing in manual assembly production, see Thomas Hout and Jean Lebreton, "The Real Contest Between America and China," *Asian Wall Street Journal,* September 16, 2003.

[3] Ronald J. Oakley, *God's Country: America in the Flies,* (New York: Red Dembner Enterprises, 1986), 239.

[4] Joseph Schumpeter, *Capitalism, Socialism and Democracy* (New York: George Allen & Unwin Ltd.,1975), 132.

[5] Total private industrial research and development expenditures as a share of GDP grew 28 times from 1920 to 1960 (0.07 percent to 2.0 percent). By the mid-1950s, over 3,000 companies had R&D facilities. Public and private R&D expenditures grew from $3.6 billion in 1940 to $23 billion in 1967 (in constant dollars). See *http://www.nsf.gov/sbe/srs/seind00/c1/tt01-03.htm.*

[6] The process was the same with scientists. The 1900 census had only two scientific occupations: chemical assayers and metallurgists.

[7] Under the census categories, 'inventor' was a separate occupation since 1900, but was downgraded to a title within professional workers not elsewhere classified in 1940.

[8] Robert D. Atkinson, "The Globalization of R&D and Innovation: How Do Companies Choose Where to Build R&D Facilities?" October 4, 2007, Testimony to the House Science Committee, *http://www.itif.org/index.php?id=102*; Richard Rosenbloom and William J. Spencer. Eds. *Engines of Innovation: U.S. Industrial Research at the End of an Era* (Boston, Massachusetts: Harvard Business School Press, 1996).

[9] Richard Florida, "The World is Spiky," *Atlantic Monthly,* October 2005, 48–51, *http://www.isites.harvard.edu/fs/docs/icb.topic30774.files/2-2_Florida.pdf.*

[10] Pre-competitive research is defined as everything before the development of a saleable prototype.

[11] Raymond E. Corey, *Technology Fountainheads: The Management Challenge of R&D Consortia* (Boston: Harvard Business School Press, 1997); Andrew P. Cortell, *Mediating Globalization: Domestic Institutions and Industrial Policies in the United States and Britain* (Albany, New York: SUNY Press, 1997).

[12] Robert D. Atkinson *et. al,* "Addressing the STEM Challenge by Expanding Specialty Math and Science High Schools," Information Technology and Innovation Foundation, March 2007, *http://www.itif.org/publications/addressing-stem-challenge-expanding-specialty-math-and-science-high-schools.*

[13] Authors' analysis of data on scientific articles from National Science Foundation, "Science and Engineering Indicators 2008," National Science Foundation, 2008, Appendix Table 5–34; population data from the World Bank World Development Indicators database.

[14] Organization for Economic Co-operation and Development, *OECD Science, Technology and Industry Scoreboard 2007, http://ocde.p4.siteinternet.com/publications/doifiles/922007081P1G2.xls.*

[15] Organization for Economic Co-operation and Development, *OCED S&T and Industry Outlook,* 2004.

[16] Organization for Economic Co-operation and Development, *OECD Science, Technology and Industry Scoreboard 2005,* 2005.

[17] U.S. Bureau of Economic Analysis, "U.S. Current-Account Deficit Increases in 2006," News Release, March 14, 2007, *www.bea.gov/newsreleases/international/transactions/2007/pdf/transannua106_fax.pdf.*

[18] "Science and Engineering Indicators: 2010," National Science Foundation, 2010, *http://www.nsf.gov/statistics/seindl0/cO/cOs3.htm.*

[19] Booz Allen Hamilton and INSEAD, "Innovation: Is Global the Way Forward?" (n.p.: Booz Allen Hamilton, 2006), 3.

[20] U.S. Bureau of Economic Analysis, "Real Value-Added by Industry."

[21] While venture capital in the United States more than doubled from $113 billion in 1996 to $26.4 billion in 2006, the amount invested in startup- and seed- stage deals fell from $1.3 billion to $1.1 billion. The amount invested in early-stage deals rose from $2.8 billion to $4.0 billion between 1996 and 2006, but the early-stage share of total venture funding fell from about 25 percent to about 15 percent. Similarly the number of startup- and seed-stage deals fell from 504 to 342; the number of early-stage deals rose from 762 to 918, but this represented a relative decline from about 30 percent to about 25 percent of all deals. Authors' analysis of 2006 data

from PricewaterhouseCoopers/National Venture Capital Association MoneyTree Report, available at *https://www.pwcmoneytree.com/MTPublic/ns/nav/jsp?page=historical.*

[22] Titus Galama and James Hosek, *U.S. Competitiveness in Science and Technology* (Santa Monica, California: RAND Corporation, 2008), 67.

[23] Organization for Economic Co-operation and Development, *OECD Science Technology and Industry Scoreboard 2005.*

[24] Organization for Economic Co-operation and Development, *OECD Science, Technology, and Industry Scoreboard 2007,* 2007, *http://oecd.p4.siteinternet.com/publications/doifiles/922007081PIG2.xls.*

[25] Norman Augustine, *Is America Falling Off the Flat Earth?* (Washington: National Academies Press, 2006), 53.

[26] Jeffrey L. Furman and Richard Hayes, "Catching up or standing still? National innovative productivity among 'follower' countries, 1978–1999," *Research Policy* 33 (2004): 1329–1354.

[27] See Abe Tadahiko, "What is Service Science?" Research Report 246, Fujitsu Research Center, Tokyo, Japan, December 2005. The *America COMPETES Act* calls for a National Academy of Sciences study of service science (a useful first step) but does not create any means for the Federal Government to advance this discipline or diffuse its findings to foster innovation in services. See *America COMPETES Act,* section 1005, P.L. 110–69, 121 Stat. 593 (2007).

[28] Issues of the State Science and Technology Institute's *Weekly* Digest provides examples (*www.ssti.org*).

[29] *In this context, "civilian" means non-defense-focused technology and innovation promotion agencies focusing on private sector and non-defense public sector technology and innovation funding and support.*

[30] Information about foreign technology and innovation-promotion agencies is from the following sources: Denmark-Danish Technological Institute Web site, *www.danishtechnology.dk;* Finland—Tekes Web site, *www.tekes.fi/eng,* and personal communication with Peter Westerstråhle of Tekes; *France—OECD Reviews of Innovation Policy:* France (Paris: Organization for Economic Cooperation and Development, 2006); Iceland—Technological Institute of Iceland Web site, *www.iti.is/english;* Ireland—Enterprise Ireland Web site, *www.enterprise-ireland.com;* Japan—NEDO Web site, *www.nedo.go.jp/english,* and personal communication with Hideo Shindo of NEDO; Netherlands—TNO Web site, *www.tno.nl/index.cfm?Taal=2;* New Zealand—New Zealand Trade and Enterprise Web site, *www.nzte.govt.nz;* Norway—Innovation Norway Web site, *www.innovasjonnorge.no;* South Korea—Korea Industrial Technology Foundation Web site, *http://lenglish.kotef.or.kr;* Spain—CDTI Web site *www.cdti.es/index.asp?idioma=es&r-1024*768;* Sweden-Vinnova Web site, *www.vnnova.se/misc/menyer-och-funktioner/Global-meny/In-English;* Switzerland-CTI Web site, *www.bbt.admin.ch/kti/index.html?lang=en;* United Kingdom Technology Strategy Board Web site, *www.dti.gov.uk/innovation/technologystrategyboard.*

[31] It is difficult to obtain information on actual results. However, discussions with government officials suggest that overall, the programs have been successful. Moreover, agencies work to improve performance. For instance, Tekes conducts regular evaluations of specific programs. An example of such an evaluation may be found at *http://www.tekes.fi/julkaisut/FENIX_arviointi.pdf* (in Finnish, with English summary).

[32] Technology Strategy Board Web site, *www.dti.gov.uk/innovation/technologystrategyboard/page40223.html.*

[33] Tekes Web site, *http://tekes.fi/eng/contact/personnel/hallitus.htm.*

[34] Technology Strategy Board Web site, *www.dti.gov.uk/innovation/technologystrategyboard/page40218.html.*

[35] United Kingdom Cabinet Office, "Public Bodies: A Guide for Departments," (June 2006).

[36] Expenditures for Finland, Sweden, Japan and South Korea are based on personal correspondence between the authors and representatives of the respective nations' innovation-promotion agencies. Inference for the United States is from the authors' analysis.

[37] Testimony of Don Hillebrand, Ph.D., Director, Center of National Transportation Research at Argonne National Laboratory, to House Appropriations Subcommittee on Energy and Water Development, February 14, 2008.

[38] Auto Industry UK, "Germany invests €420M in lithium-ion battery development," May 13, 2008, *http://www.autoindustry.co.uk/news/13-05-08_2.*

[39] Forfas, *Service Innovation in Ireland—Options for Innovation Policy,* (Dublin, Ireland: Forfas, September 2006), 10, *http://www.forfas.ie/media/forfas060928_services_innovation_full_report.pdf.*

[40] €100 million converted into $120 million according to exchange rates at the time. (€100 million converts to $135 million in today's dollars.)

[41] Tekes, the Finnish Funding Agency for Technology and Innovation, € (Helsinki, Finland: Tekes, 2006).

[42] While this is a small sampling, a comprehensive inventory of European services innovation policies is available via the European Innovation Policy Project in Services available at *http://www.europe-innova.org/serv/et/Doc?cid=9268&lg=EN.*

[43] Robert D. Atkinson, "Expanding the R&D Tax Credit to Drive Innovation, Competitiveness and Prosperity," Information Technology and Innovation Foundation, April 2007, *http://www.itif.org/node/1280.*

[44] Bronwyn Hall and John van Reenen, "How Effective Are Fiscal Incentives for R&D? A Review of the Evidence," *Research Policy 29* (2000): 449–469.

[45] Dominique Guellec and Bruno van Pottelsberghe de la Potterie, "Does Government Support Stimulate Private R&D?" *OECD Economic Studies 29* (1997).

[46] In fact, government support declined significantly over this period and as a result, the United States was one of the few nations where the share of R&D-to-GDP ratio fell between 1991 and 2002.

[47] Martin Falk, "What Drives Business R&D Intensity Across OECD Countries?" Paper Presented at the DRUID 10th Anniversary Summer Conference, Copenhagen, Denmark (June 27–29, 2005).

[48] In 1985, the rate was reduced from 25 to 20 percent, and other restrictions (such as the 50 percent rule and the recapture of benefits through reductions in expensing) were put in place in the late 1980s.

[49] K.C. Whang, *A Guide to the Research Tax Credit: Why We Have It, How It Works, and How It Can Be Improved* (Washington, DC: U.S. Congress, Working Paper Series, Offered to the Joint Economic Committee Minority, Dec. 1998).

[50] Robert Atkinson and Scott Andes, "U.S. Continues to Tread Water in Global R&D Tax Incentives," Information Technology and Innovation Foundation, 2009, *http://www.itif.org/filesJWM-2009-03-rd.pdf.*

[51] David M. Hart, "Global Flows of Talent: Benchmarking the United States," Information Technology and Innovation Foundation, November 2006, 12, *http://www.itif.org/files/Hart-GlobalFlowsofTalent.pdf.*

[52] Australian data are drawn from the Australian Department of Immigration and Multicultural Affairs (DIMA) *annual Immigration Update, http://www.immi.gov.au/media/publications/statistics/*. New Zealand data are drawn from OECD, SOPEMI 2006, 303–304. Canadian data are drawn from Citizenship and Immigration Canada annual Facts and Figures, accessible at *http://www.cic.gc.ca/english/research/menu-fact.html.* All figures are for principal applicants only.

[53] However, the 65,000 cap doesn't apply to all countries. For example the United States-South Korea Free Trade Agreement allows for a higher number of H–1B visa applicants from South Korea.

[54] Gregory Tassey, "Rationales and Mechanisms for Revitalizing U.S. Manufacturing R&D Strategies," December 2009, forthcoming in *Journal of Technology Transfer,* June 2010.

[55] Elvio Accinelli, Silvia London, and Edgar J. Sanchez Carrera, "Complimentarity and Imitative Behavior in the Populations of Firms and Workers," 2008, *http://www.ssrn.com/abstract=1136323,* (accessed on February 28, 2008).

[56] See Charles I. Jones and John Williams, "Measuring the Social Return to R&D," *Quarterly Journal of Economics* 113 (1998): 1119–1135; Edwin Mansfield, "Social Returns from R&D: Findings, Methods, and Limitations," Research Technology Management 34 (1991): 24–27; Eric Brynjolfsson, Lauren Hitt, and Shinkyu Yang, "Intangible Assets: How the Interaction of Information Technology and Organizational Structure Affects Stock Market Valuations," Brookings Papers on Economic Activity 1, (2000): 137–199.

[57] On the conflict between firms' desires to appropriate university research capacity and universities' broader social and economic role in promoting the free flow of knowledge, see Richard K. Lester and Michael J. Piore, *Innovation: The Missing Dimension* (Cambridge: Harvard University Press, 2004).

[58] Daniel Castro, "Improving Health Care: Why a Dose of IT May Be Just What the Doctor Ordered," Information Technology and Innovation Foundation, 2007, *http://www.itif.org/node/1238.*

[59] Shane Ham and Robert Atkinson, "Modernizing Home Buying: How IT Can Empower Individuals, Slash Costs, and Transform the Real Estate Industry," Progressive Policy Institute, 2003.

[60] Barry LePatner, *Broken Buildings, Busted Budgets: How to Fix America's Trillion-Dollar Construction Industry* (Chicago: University of Chicago Press, 2007).

[61] For a comprehensive overview of the causes and consequences of geographic industry clustering, see Joseph Cortright, *Making Sense of Clusters: Regional Competitiveness and Economic Development* (Washington: Brookings Institution, 2006). On the geographic clustering of innovation and the special importance of large metropolitan areas for innovation, see Andrew Reamer with Larry Icerman and Jan Youtie, *Technology Transfer and Commercialization: Their Role in Economic Development* (Washington: U.S. Department of Commerce, Economic Development Administration, 2003), 57–110.

[62] The authors' analysis of Bureau of Economic Analysis data on value added and employment at the national level and Economy.com data on the geographic distribution of industry employment shows that, for the 17 nongovernmental industry supersectors other than real estate (accommodation and food services; administrative and waste management services; arts, entertainment, and recreation; construction; educational services; finance and insurance; health care and social assistance; information; management of companies and enterprises; manufacturing; mining; other services; professional, scientific, and technical services; retail trade; transportation and warehousing; utilities; and wholesale trade), the cross-industry correlation between an industry's Herfindahl index of employment concentration at the county or metropolitan level (a measure of the extent to which an industry is geographically concentrated rather than spread out evenly across the nation) at the beginning of the business cycle and the growth of inflation-adjusted value added per job in the industry over the course of the business cycle increased over the course of the 1979–89, 1989 2000, and 2000–05 periods. (Business cycles here are approximated by periods that begin and end in the last pre-recession year. The most recent period ends in 2005 because of data limitations.) At the county level, the correlation coefficient rose from −0.18 in 1979–89 to −0.07 on 1989–2000 to 0.36 in 2000–05. At the metropolitan level, it rose from −0.12 in 1979–89 to 0.00 in 1989–2000 to 0.15 in 2000–05.

[63] For a detailed treatment of this issue in the context of international trade, see Ralph Gornory and William J. Baumol, − (Cambridge, Massachusetts: MIT Press, 2000).

[64] Dani Rodrik, "Industrial Policy for the Twenty-First Century," Kennedy School of Government Working Paper, Harvard University, 2004, 38.

[65] Dan Breznitz, *Innovation and the State* (New Haven, Connecticut: Yale University Press, 2007), 29.

[66] Annual U.S. trade deficits have subsequently shrunk somewhat, to $731.2 billion in 2007 and to $673.3 billion in 2008; however, these annual trade deficits are still extremely high.

[67] "S.1466: Trade Enforcement Act of 2009," Govtrack.us, 13, *http://www.govtrack.us/congress/bill.xpd?bill=s111-1466.* See also Robert Atkinson, "Combating Unfair Trade Practices in the Innovation Economy," Testimony before the Committee on Finance, United States Senate, May 22, 2008, *http://www.itif.org/files/atkinsonfinancecommitteetestimony.pdf.*

[68] Robert D. Atkinson *et. al,* "Addressing the STEM Challenge by Expanding Specialty Math and Science High Schools."

[69] Many MSHS students are able to take these extra courses by taking regular education graduation requirements such as Economics, American Government, Physical Fitness, and Health online at the Florida Virtual High School.

[70] Source for national figures are: U.S. Department of Education, National Center for Education Statistics, "Digest of Education Statistics," Table 18, *http://nces.ed.gov/programs/digest/d05/tables/dtO5_181.asp,* and U.S. Department of Education, National Center for Education Statistics, "2000101 Baccalaureate and Beyond Longitudinal Study," *http://nces.ed.gov/das/library/tables_listings/show_nedre.asp?rt=p&tableID=1378.*

[71] Some of the expansion would come from construction and creation of new MSHSs. Costs for building such a high school can range from around $11 million (for rehabilitating an existing building) to over $50 million for constructing a new MSHS in an area where land prices are more expensive. Some expansion of enrollment would come from expanding existing high schools, where the price would presumably be less. However, even at these schools the costs can be higher, particularly for more extensive laboratory equipment. Overall these funds will be used as an incentive to spur states and local school districts to create more specialty math and science high schools.

[72] Richard Freeman, "Investing in the Best and the Brightest: Increased Fellowship Support for American Scientists and Engineers," The Brookings Institute, 2006, *http://www.brookings.edu/views/papers/200612freeman.pdf.*

[73] Established in the early years of NSF, the program provides the nation's most promising graduate students with great flexibility in selecting the university of their choice and gives them the intellectual independence to follow their research ideas unfettered by the exigencies of mode of support.

[74] Donald Wulff, Ann Nquiest, and Jo Sprague, "The Development of Graduate Students as Teaching Scholars: A four-year longitudinal study," in *Paths to the professoriate: Strategies for enriching the preparation of future faculty,* ed. Donald Wulff and Ann Austin (San Francisco: University of Chicago Press, 2006); Chris Golde and Timothy Dore, "At Cross Purposes: What the experiences of today's doctoral students reveal about doctoral education," Pew Charitable Trusts, 2001, *http://www.phd-survey.org/report%20final.pdf.*

[75] Jody Nyquist , BJ Woodford , and Dale Rogers, "Re-envisioning the Ph.D.: A challenge for the twenty-first century," in *Paths to the professoriate: Strategies for enriching the preparation of future faculty,* ed. Donald Wulff and Ann Austin (San Francisco: University of Chicago Press, 2006).

[76] Chris Golde and Timothy Dore, "At Cross Purposes: What the experiences of today's doctoral students reveal about doctoral education."

[77] Steven Campbell, Angela Fuller and David Patrick, "Looking beyond research in doctoral education," *Frontiers in Ecology and the Environment,* 3, no. 3, (2005), *http://www.biology.duke.edu/jackson/ecophys/153-160_ESA_April05.pdf*

[78] Moreover, research suggests that there is little difference in ethical behavior by faculty whether they are funded by industry or government; see Brian Martison, Lauren Crain, Melissa Anderson, and Raymond De Vries, "Institutions' Expectations for Researchers' Self Funding, Federal Grant Holding, and Private Industry Involvement: Manifold Drivers of Self-Interest and Research Behavior," Academic Medicine, 84, no. 11 (2009).

[79] Government Accountability Office, "Streamlined Visas Mantis Program Has Lowered Burden," GAO 05–198, February 2005, *http://www.gao.gov/new.items/d05198.pdf*

[80] David Hart, "Global Flows of Talent: Benchmarking the United States."

[81] U.S. Small Business Administration, "Description of the Small Business Technology Transfer Program," STIR, *http://www.sba.gov/aboutsba/sbaprograms/sbir/sbirstir/SBIR_STTR_DESCRIPTION.html.*

[82] Dan Berglund, State Science and Technology Institute, in-person interview with Rob Atkinson, January, 2010.

[83] Connecticut's Yankee Ingenuity program and Pennsylvania's Ben Franklin Technology Partners program work in a similar manner. See Yankee Ingenuity Competition, *http://www.ctinnovations.corn/funding/ccef/yankee.php* and Ben Franklin Technology Partners, *http://www.benfranklin.org/about/index.asp.*

[84] The Great Lakes Entrepreneur's Quest, a program in Michigan, is similar. Its organizers represent Michigan's entrepreneurial community: academics, investors, lawyers, CPAs, corporate executives and other entrepreneurs. Program gives competitors a chance to win seed capital and valuable services (e.g., legal, accounting, and consulting) and provides other opportunities to help entrepreneurs launch or grow a business.

[85] This kind of assistance to states with unsuccessful proposals is based on similar assistance that JumpStart, a nonprofit pre-venture capital fund in the Cleveland area, and Adena Ventures, an Athens, OH-based venture capital firm, provide to applicants whose proposals are not yet fundable. See *www.jumpstartinc.org/Process/Assist.aspx* and *www.adenaventures.com/serviceprograrns/opsassist.aspx.*

[86] Jane E. Fountain and Robert D. Atkinson, *Innovation, Social Capital, and the New Economy: New Federal Policies to Support Collaborative Research,* Progressive Policy Institute, July 1998, *http://www.ppionline.org/ppi_ci.cfxn?knlgAreaID=140&subseclD=293 &contentID=1371.*

[87] L. Branstetter and M. Sakakibara, "Japanese Research Consortia: A Microeconometric Analysis of Industrial Policy," *Journal of Industrial Economics,* 46 (1998): 207–233.

[88] For example, spillovers from company-funded basic research are very high—over 150 percent according to one study: Albert Link, "Basic Research and Productivity Increase in Manufacturing: Additional Evidence," *The American Economic Review,* 71, no. 5 (Dec. 1981): 1111–1112.

[89] According to NSF, industrial R&D support to U.S. universities and colleges in current dollars reached its peak in 2001 and has declined every year since then (to 2004). The share of academic R&D provided by industry peaked in 1999 and has declined every year since. See Alan I. Rapoport, "Where Has the Money Gone? Declining Industrial Support of Academic R&D," National Science Foundation, Division of Science Resources Statistics, September 2006, *http://www.nsf.gov/statistics/infbrief/nsf06328/*.

[90] Barry Bozeman and Albert N. Link, "Tax Incentives for R&D: A Critical Evaluation," *Research Policy* 13, no. 1 (1984): 21–31.

[91] Denmark looks to promote public and private co-operation in R&D by having a 150 percent deduction of investments co-financed by a public university or research institute and the industry.

[92] Jacek Warda, "Tax Treatment of Investment in Intellectual Assets: An International Comparison," *OECD Science, Technology and Industry Working* Papers, 4, 2006, Appendix 1.1.

[93] Expenditures firms make to outside organizations are treated two ways. Qualified expenses cover just 65 percent of payments for contract research, unless the payments are to a qualified non-profit research consortium at which point the company can count 75 percent of the payments as qualified expenses. However, firms contracting with certain nonprofit organizations (e.g. universities) to perform basic research may claim a credit of 20 percent.

[94] The 109th Senate considered versions of HR.4297 (Thomas, (R–CA)), S.14 (Stabenow (D–MI)), S.2199 (Domenici (R–NM)), and S.2357 (Kennedy (D–MA)). S.2357 would institute a flat credit for payments to qualified research consortia.

[95] Donald Stokes, "Pasteur's Quadrant," Brookings Institution, 1997.

[96] See the Focus Center Program, *http://fcrp.src.org/member/about/about_centers.asp.*

[97] Robert Atkinson and Howard Wial, "Boosting Productivity, Innovation, and Growth Through a National Innovation Foundation," Information Technology and Innovation Foundation and The Brookings Institution, April 2008, *http://www.itiF.org/publications/boosting-productivity-innovation-and-growth-through-national-innovation-foundation.*

[98] This is based on a report by Stuart Benjamin and Arti Rae, "Structuring U.S. Innovation Policy: Creating a White House Office of Innovation Policy," Information Technology and Innovation Foundation, June 2009, *http://www.itif.org/files/WhiteHouse_Innovation.pdf.*

BIOGRAPHY FOR ROBERT D. ATKINSON

Robert Atkinson is the founder and president of the Information Technology and Innovation Foundation, a Washington, DC-based technology policy think tank. He is also author of the State New Economy Index series and the book, *The Past And Future Of America's Economy: Long Waves Of Innovation That Power Cycles Of Growth* (Edward Elgar, 2005). He has an extensive background in technology policy, he has conducted ground-breaking research projects on technology and innovation, is a valued adviser to state and national policy makers, and a popular speaker on innovation policy nationally and internationally.

Before coming to ITIF, Dr. Atkinson was Vice President of the Progressive Policy Institute and Director of PPI's Technology & New Economy Project. While at PPI he wrote numerous research reports on technology and innovation policy, including on issues such as broadband telecommunications, Internet telephony, universal service, e-commerce, e-government, middleman opposition to e-commerce, privacy, copyright, RFID and smart cards, the role of IT in homeland security, the R&D tax credit, offshoring, and growth economics.

Previously Dr. Atkinson served as the first Executive Director of the Rhode Island Economic Policy Council, a public-private partnership including as members the Governor, legislative leaders, and corporate and labor leaders. As head of RIEPC, he was responsible for drafting a comprehensive economic strategic development

plan for the state, developing a ten-point economic development plan, and working to successfully implement all ten proposals through the legislative and administrative branches. Prior to that he was Project Director at the former Congressional Office of Technology Assessment. While at OTA, he directed The Technological Reshaping of Metropolitan America, a seminal report examining the impact of the information technology revolution on America's urban areas.

He is a board member or advisory council member of the Alliance for Public Technology, Internet Education Foundation, NetChoice Coalition, the Pacific Institute for Workforce Innovation, and the University of Oregon Institute for Policy Research and Innovation. He is also chair of the Congressionally-created National Surface Transportation Infrastructure Financing Commission. He also serves on the advisory panel to Americans for Computer Privacy, is an affiliated expert for the New Millennium Research Council, a member of the editorial board of the Journal of Electronic Government and the Journal of Internet Policy, a member of the Reason Foundation's Mobility Project Advisory Board, a member of the Global Innovation Forum Brain Trust and a Nonresident Senior Fellow at the Brookings Institution. Dr. Atkinson was appointed by President Clinton to the Commission on Workers, Communities, and Economic Change in the New Economy. He is also a member of the Task Force on National Security in the Information Age, co-chaired by Markle Foundation president Zoe Baird and former Netscape Communications chairman James Barksdale. In 1999, he was featured in "Who's Who in America: Finance and Industry." In 2002, he was awarded the Wharton Infosys Business Transformation Award Silver Medal. In addition, Government Technology Magazine and the Center for Digital Government named him one of the 25 top Doers, Dreamers and Drivers of Information Technology. In 2006, Inc. Magazine listed Atkinson as one of 19 Friends of Small Business in Washington. Ars Technica listed Atkinson as one of 2009's tech policy People to Watch. Dr. Atkinson has testified before a number of committees in Congress and has appeared in various media outlets including CNN, Fox News, MSNBC, NPR, and NBC Nightly News. He received his Ph.D. in City and Regional Planning from the University of North Carolina at Chapel Hill in 1989.

Chairman WU. Thank you very much, Dr. Atkinson.

Dr. Breznitz, please proceed.

STATEMENT OF DR. DAN BREZNITZ, ASSOCIATE PROFESSOR, THE SAM NUNN SCHOOL OF INTERNATIONAL AFFAIRS, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. BREZNITZ. Mr. Chairman and Members of the Committee, thank you for the opportunity to take part in this hearing. In this testimony, I hope to do three things: clarify some baseline points with regards to innovation policy, give an example of successful foreign innovation policy, its negative and positive consequences, conclude by sketching the need for the United States to concentrate on all three roles government can play in stimulating more innovation, and urge for new Federal-state partnerships.

There are some baseline points to be made when discussing innovation policy. Stimulating and promoting innovation is a critical role of government and is a very different strategic exercise from promoting specific industries, sectors, or even skills. Good innovation policies need to allow experimentation and change. In order to promote innovation, there is a need to balance with different interests of the public represented by the elected government and the private actors who are going to be the major agents of innovation in our country.

Two key strategic constraints: When you talk about innovation-based growth, it calls for a different logic of policies. You have undefined markets and undefined products. You basically aim to come up with new technologies and new products which you don't know what they are. It is a very different exercise when trying to restructure the car industry where we know what cars are, we know

what the troubles are, we know what the markets are, and we have a pretty good idea of how to make better cars and what skills we need. When we think about the ideal kind of innovation policy, we aim to equip the economy with agents of change that are stimulated for action in ways we cannot yet foresee.

Second, production is now globally fragmented. Activities, not whole industries, are clustered in specific nations and we have to take that into account if we want to understand how our innovation activities are going to impact job growth in this country. Government needs to make innovation less risky and more rewarding for entrepreneurs in order to maximize innovating activities. It also needs to ensure positive global-local interconnection in order to maximize our national spillovers. The ways in which different countries have successfully done this have led to very diverse national industries with different outcomes in terms of economic distribution as well as the current and future challenges each of those models have.

To optimize the impact of a public funding of innovation, governments need to meet three challenges: trust—the need to establish trust between government and those private actors and we need the private actors themselves; coordination—the need to coordinate R&D across different institutional actors; and motivation—the need to motivate private actors to innovate in a way that contributes to the domestic economy, which is the main reason for public funding in the first place.

Broadly speaking, there are three roles by which government successfully supports this: public finance of private innovation where, if a government supplies capital to private agents who use it to engage in R&D, public production of innovation and a facilitator role. Here the main emphasis is on the government role in anchoring professional interinstitutional networks and more generally on the government's role in fostering relations with and between private actors. The importance of these facilitating policies cannot be overemphasized as government-sponsored networks have been shown to be one of the most important factors for creation of a favorable environment for radical innovation, and Dr. Atkinson just mentioned the semiconductor industry.

Let me give you the example of Israel. Facing crisis starting in 1968 with 886 R&D workers with academic education in the whole industrial sector, probably less than what we have in this building right now, the government opted to focus on what they called science-based industry and concentrated on financial and facilitator roles, implementing horizontal R&D policy, meaning trying to sponsor R&D activities to novel products in all industries, all sectors, and emphasizing the conduction of the local and the global, especially with the United States, the BIRD [Binational Industrial Research and Development] Foundation, which is cosponsored by the U.S. government and the Israeli government, and anchoring cooperation around innovation. Outcomes have been the great success of Israel as the supplier of new technologies and products, the largest number of high-tech companies after the United States—more than the EU in total—and the challenges, however, with industry migrates to the United States, exactly the opposite of what we think about in globalization, building of sustainable success and

major economic inequality, mainly because you have a high-tech sector but you have measurable positive spillover to the rest of the economy.

To conclude, innovation policy can significantly enhance economic growth and national competitiveness. Innovation policies are contact specific and need to evolve in tandem with industry. To be successful at implementing innovation policies, government needs to be able to engage in all three roles: financier, producer and facilitator. In the U.S., much attention has been given to the financier role. I argue that much more attention needs to be given to the facilitator role, and in order to be successful in this, we have to devise new, and build upon old, Federal-state partnerships as well as public-private partnerships. I think it is time that we apply innovation to our own innovation policies.

Thank you for the hearing.

[The prepared statement of Dr. Breznitz follows:]

PREPARED STATEMENT OF DAN BREZNITZ

Chairman Wu, Ranking Member Smith, and members of the Subcommittee, thank you for the opportunity to take part in this hearing. I was invited here to talk about innovation for economic growth, and what we can learn from the extensive efforts of other nations to excel in this domain so we can secure the long-term economic welfare of the American people.

There are some baseline points to be made when discussing innovation policy:

1. Spurring and promoting innovation is a critical role of government, and is a very different strategic exercise from promoting specific industries, sectors, or even skills.
2. Good innovation policy needs to allow experimentation and change as it, and the industries it helps to develop, evolve.
3. In order to promote innovation there is a need to balance the different interests of the public, represented by the elected government, and private companies and individuals that will be the major agents of innovation in our country.

Current U.S. policy debates have been clouded by significant misunderstandings in relation to these principles. A careful analysis of other nations' efforts to use the tremendous forces of competition and entrepreneurship to spur innovation, can help us sort out these misunderstandings and improve our innovation policies.

In this testimony I will:

1. Lay out the challenges associated with government efforts to enable innovation.
2. Describe three roles a government can take on to support rapid innovation-based growth and illustrate how some other countries have implemented policies to fill these roles.
3. Discuss the lessons the U.S. might take from international experiences in innovation policy.

Innovation, growth and the U.S.

Innovation has been a tremendous force for good. Innovations in industry, health, and agriculture have advanced the quality of life of the American people to such a degree that today the average American child has a much better, more comfortable, luxurious, and healthy life than the Emperor of China had in the beginning of the 20th century. Thanks to innovation, the world no longer faces imminent hunger, diseases that were once both common and fatal are vanquished, and the sum set of appliances in an average American home gives its owner the ability to do things that were impossible with a regiment of workers and scholars just a few generations ago. We might forget, but what we now consider as low-tech traditional industries, were, only a few decades ago, the cutting edge of high-technology. Indeed, in the 1967 movie, *The Graduate,* Mr. McGuire famously said to Benjamin one word that embodied the future of industrial innovation: "Plastics." For this country to stay a world leader, our children will need to be able to react in the same bemused

way we do to the idea of plastics as the future, when someone in circa 2050 would say: "Nano-technology."

The U.S. has grown to prominence as *th*e place where people with vision and drive can become educated, generate novel ideas, and secure specialized financing to transform their ideas into superior products and services. Furthermore, it was in the U.S. where one could pursue that course without its being squashed in infancy by stronger corporations, the legal system, or the growing costs of doing business and staying independently employed. With each new innovation-based revolution—agriculture, steel, electricity, internal combustion engine, aviation, space, information technology, and biotechnology—the U.S. has led the world, becoming richer and stronger as a result. This has been true not only with regard to novel technologies brought to the market for the first time, but with regard to new ideas all along the production chain. To accomplish this, the United States has developed the world's best centers of higher education and research and the world's most efficient system for transforming ideas into marketable realities. Today, however, in each and every part of this system we face increased international competition.

Choices matter

Contrary to commonly held belief, the current processes of intensified globalization give countries a larger number of rapid-innovation-based economic growth alternatives than they had in the past. A general truism today is that both the onslaught of international economic forces and the fragmentation of production limit the power of governments to set unique courses of successful economic growth. And yet, these same conditions have given countries more choices of action than ever before, for the increasing complexity and openness of the world allow nations that wish to engage with the international economic system a far larger number of entry points than in any other period. This does not mean that stimulating development has become an easier task for government, nor that success, if it is achieved, is without cost.

Rapid-Innovation-Based growth—the misunderstood strategic policy implication

The case of rapid-innovation-based growth presents a variety of problems for those who try to understand the role of government. Since the main aim is to bring to fruition novel ideas—ideas that cannot be known in advance—for products and services that are as yet unimagined, we cannot develop policies assuming that we know the markets, the products, the industries, the specific skills needed, or how they will be combined (Breznitz 2007b). This is not the case of developing or restructuring an existing industry, such as the car industry, where the products are well understood, and where we have a clear idea of how to make them, and a pretty good guess about the capabilities we would need to make better vehicles.

In the case of innovation, the aim of the government is to spur agents, some of whom are currently unknown or do not yet exist, to come up with novel ideas and transform them into products and services, which, as of now, cannot be defined. Accordingly, in its idealized form innovation policy aims to equip the economy with agents of change that are stimulated for actions in ways we cannot foresee. Furthermore, with globalization—that is, the growing fragmentation of production where products are produced in discreet stages across many locales—we at best have only a limited ability to predict the exact division of labor between the local agents and the international economy that would allow for the making and sale of these products and services for maximum profits. Hence, we need to develop agents (both individuals and organizations) that have the capacity to understand science and technology as well as the market, and the capability to generate novel ideas. In addition, we need to ensure that they work within a system that enables them, as smoothly as possible, to transform these ideas into products and services to be sold worldwide.

What we do know, however, is that the inherent characteristics of industrial research and development (R&D) would lead, under free competitive market conditions, to under-investment in innovation from a social optimum point of view (Arrow 1962; Nelson 1959). For this reason almost every nation on earth now engages in public funding of innovation in an attempt to lower the risk and stimulate more activity. Similarly, many nations now try to increase the rewards for innovation in the hope of making them more attractive. This is part of the logic behind systems, such as the patent system, that grant monopoly rights to inventors who come up with ideas that are deemed original. Consequently, in our era of globalization governments now need to actively engage in two critical domains: i) solutions to the industrial R&D market failure; ii) local-global relationships. My research has found that different countries successfully solve these issues in very different ways, leading to

significantly varied outcomes both in the scope of activities and in the distribution of the economic fruits of success within their societies.

None of these issues are considered to be outside the mainstream of policy and theory. Most scholars and policy makers would fully agree that there is a need for public funding of industrial R&D. However, the common policy prescription urges government to go no further than minimal 'market-enhancing' intervention. It is here where the most common misunderstandings about innovation policy occur.

Three Challenges

Once governments commit to funding of industrial R&D, a host of issues that are not fully acknowledged in policy debates and theory comes into play. Specifically, nations that subsidize industrial R&D face three overlapping challenges (Breznitz and Zehavi 2010):

1. Trust: the need to establish trust both between public and private actors and among private actors.
2. Coordination: the need to coordinate R&D across institutional actors. Both the trust and coordination challenges are closely associated with the overarching goal of establishing cooperation among private and quasi-private actors.
3. Motivation: the need to motivate private actors to innovate in ways that contribute to the domestic economy—the prima facie reason for public funding in the first place.

Trust: The importance of trust for industrial R&D is manifested in two different types of relationships: trust between the government and private actors and trust among the private actors themselves. The 'trust' deficit with regard to 'government-private' relations is associated with the problem of information asymmetries. One of the government's main objectives in financing R&D is the creation of new industries and the introduction of new activities into the local economy. As a consequence, by definition, markets are either underdeveloped or not yet in existence. Under these circumstances, the government cannot rely on market signals to ensure that: a) its investments are used properly; and b) that its policies lead to the stated goal of creating new industries and capabilities within the national economy. Because governments cannot fully rely on the market for information, adherence to a pure financier/provider division might create significant information asymmetry problems between the government and private firms. Even in the private market it is assumed that these problems can never be optimally resolved, and hence, that financing of new R&D-based companies is, supposedly, best handled by specialized financiers, such as venture capitalists, who use a variety of instruments to negate, but can never fully eliminate, these information asymmetries.

Second, as we have learned from the multidisciplinary study of innovation in the last few decades, innovation is a collective endeavor that necessitates close cooperation among agents if it is to flourish and result in long-term economic growth (Antonelli 2000; Carlsson et al. 2002; Edquist 1997; Hagedoorn 2002; Kenney 2000; Lester and Piore 2004; Lundvall 1992; Nelson 1993; Powell et al. 1996). Therefore, for public investments in private R&D to deliver sustained economic growth there is a need to accommodate close cooperation among firms. However, against the backdrop of fully competitive free markets it is to be expected that inter-firm collaborations would be laced with suspicion and distrust. Balancing cooperation and competition is no simple matter even when firms possess complementary knowledge and capabilities. Moreover, even in situations in which private firms do choose to cooperate, insufficient trust is likely to push partners to restrict the scope of cooperation (Li, Eden et al. 2008). Government-facilitated cooperation has, over time, successfully engendered trust among cooperating private actors. Closely related to this problem, countries that rely solely on public funding to stimulate R&D growth might well discover, to their dismay, that firms are underutilizing public funding because of capacity problems in the private sector (Sustman and Teubal 1995). This problem is compounded by inter-firm competition that engenders distrust and discourages professional cooperation across firms. This is a major problem because R&D is a collaborative venture in which the interplay of different skills and ideas allows professionals to achieve together what would have been well nigh impossible on their own. Isolated professionals might well fail to make substantial breakthroughs, where the same professionals working in cooperation would have had a far better chance.

Coordination: Meaningful and sustained interaction among diverse actors that are separated organizationally, geographically, or both, is not a given regardless of concerns regarding trust. The system of innovation literature shows that private firms

that engage in R&D activities cannot operate in an optimal manner without the support of an array of other institutions (Carlsson et al. 2002; Edquist 1997; Lundvall 1992; Nelson 1993). The development of a high technology industry does not happen in an institutional vacuum. Many locales must undergo a fair amount of industrial restructuring before the conditions are right for high technology growth. For example, dynamic R&D-led industries lead to the need to have ever greater flexibility in the labor force. This flexibility must be achieved while preventing severe political backlash against innovation when it leads to deep crises in specific locales. Such a feat, however, can be accomplished only with close coordination between private market actors and public actors that work together to legitimize and facilitate flexibility-enhancing restructuring (McDermott 2007; Ornston and Rehn 2006; Traxler and Unger 1994).

Domestically-oriented Motivation: Governments would like private actors not only to be motivated to innovate, but to do so in ways that would benefit the local economy. Yet there is little assurance that this would be the case because private actors' prime need and interest is to maximize their personal utility regardless of effect on other domestic firms or the geographical locale in which their value-added activities take place. These different goals create two distinct conflicts of interests between the government, on the one hand, and private companies, on the other.

First, one of the main justifications for public support of industrial R&D is the expectation that private R&D would generate positive spillovers for the rest of the economy. The government therefore aims to maximize local spillovers from its industrial R&D investment. However, in their search for profits, companies prefer to maximize the appropriability of their R&D outcomes. Private firms do their best to create the most competitive R&D possible—certainly a public interest—but would also do their utmost to fully appropriate its benefits and limit the spillover effects—something that governments would like to prevent.

Second, governments prefer that individuals and firms contribute first and foremost locally. But what could motivate private domestic actors to stay, or for that matter, return, home? While the government hopes to keep as much high value-added business at home, commercial firms would relocate abroad if they deem such a move advantageous. The traditional economic viewpoint is that, even if commercial firms indeed choose to pick up and leave, it is all for the best because the reallocation of resources would be more efficient and benefit domestic consumers (Krugman and Obstfeld 1991). Nonetheless, the rationale for public investment in R&D is specifically to create positive spillover at home, and this will not occur if both the R&D and the diffusion of its results are conducted abroad as it is more and more the case in our globalizing world (Gomory and Baumol 2000).

The three related problems of trust, coordination and motivation are by no means unique to innovation. In the R&D field, however, these concerns are accentuated for at least three reasons. First, distrust—especially among private actors—is likely to be prevalent because of the nature of the product and also that of the firms involved. Where innovation is at the epicenter, then a firm's advantage is to be found primarily in its ability to create new know-how. Transfer of information and technology to other firms, and with it a firm's competitive advantage, is relatively easy (Lundvall 1999). Hence, firms have a strong incentive to limit the lines of communication with other firms so as not to suffer from unwelcome knowledge transfer. As a result, establishing trust between private firms is a challenging venture. Second, the R&D field is relatively internationalized compared to most other production domains. This means that coordination is likely to involve not only domestic but also international actors. Obviously, this implies an additional challenge for coordination. Finally, in R&D-intensive high-technology sectors, such as information- or biotechnology, both firms and professionals are comparatively far more footloose than in traditional industries or services (e.g., steel manufacture or healthcare). Therefore, the question of how to motivate private actors to contribute locally is more pertinent than in most other fields.

Three Government Roles, Many Games: What do other countries do?

There are three broad roles by which governments, using very different modes which are tailored to their specific conditions, support rapid-innovation-based growth:

i) public-financing of private-innovation, where the government supplies capital to private agents who use it to engage in R&D and innovation;

ii) public production of innovation, where public production is commonly understood to imply industrial R&D conducted in government research institutes, universities, and non-profit research institutes such as hospitals; and,

iii) the government acting as a facilitator, where the main emphasis here is on the government role in anchoring professional, inter-institutional networks, and more generally, on the government's role in fostering relations with—and among—private actors.

The importance of the third role, facilitating policies, cannot be over-emphasized, as government-sponsored networks have been shown to be one of the most important factors for the creation of a favorable environment for radical innovation (Godoe 2000; Kushida 2008; Kushida and Zysman 2008; O'Riain 2004). Actor interaction within these networks helps shape a common vision of the future, and R&D efforts, which are then channeled towards realizing this vision (Lester and Piore 2004). Indeed, some argue that DARPA's excellence in conducting this role in the American context is the base for its greatest successes (Fuchs, forthcoming).

Since public financing of private innovation activities is the best known and most discussed role of the three, let me briefly describe some international examples of successful usage of the two others. Taiwan has received much attention for its extremely successful application of the public production strategy. The government had mitigated the market failure and information asymmetries problems by undertaking the core R&D itself. This created a unique division of labor between government and industry in the case of the IT industry. The specificity of this division of labor stems from the state's high level of participation in the development of the technological capabilities of the industry. In this division of labor, public research institutions do most of the R&D up to the level of a working prototype, and then disseminate the results to industry, which concentrates on final development and integrated design. It is this division of labor that is considered responsible for Taiwan's leading role in the global information technology industry, most famously in semiconductors. This strategy also allowed Taiwan to create a large number of jobs—not just jobs for the very high-skilled and educated, but jobs at many levels, thereby spreading the fruits of its innovation success more widely across the society (Amsden and Chu 2003; Berger and Lester 2005; Breznitz 2007b; Fuller et al. 2003; Hong 1997; Mathews and Cho 2000; Meany 1994; Park 2000).

This public production-anchored model also addresses the capacity problem. The government concentrates scarce capacities, and by so doing, overcomes the private non-cooperation obstacle. Arundel and Geuna contend that in Europe public research is an especially important resource for firms that lack the financial resources, or capabilities, to obtain knowledge abroad (Arundel and Geuna 2004). Therefore, a case can be made for more direct public intervention in R&D. However, for such interventions to work the incentives for public R&D production should be carefully aligned with the growth and creation of a local *privately-owned* industry and the government should set a premium on bureaucratic flexibility in its research institutions. Otherwise, the negative outcomes will outweigh the positive ones.

Israel is an example of a highly successful use of the facilitator strategy. A measure of the success of its innovation policies is the fact that in 1968, when the first government committee on R&D policy was convened, there were only 886 academy-trained R&D workers in the entire industrial sector. Within three decades of implementing its new innovation policies, Israel boasted the highest number of high-tech companies listed on NASDAQ after the United States. As part of these efforts, as early as 1975, the Israeli Office of the Chief Scientist of the Ministry of Trade, Industry and Employment (OCS), Israel's main industrial innovation agency, launched a joint program with the American Government that matched local companies with American multinational corporations (MNCs). This program, known as the Bi-national Industrial R&D foundation (BIRD), concentrated on fostering and financing cooperation between Israeli and U.S. companies (BIRD 2000; Breznitz 2007a; Teubal 1997; Trajtenberg 2001; Yahalomi 1991). Its mode of operation has been to fund projects co-designed by American and Israeli companies, in which the R&D was done in Israel, and the marketing and product definition handled in the U.S. As a consequence, the Israeli government stimulated international cooperation that ensured R&D would commence in Israel, and mitigated the information asymmetries between itself and the private firms it sponsored by receiving high-quality "external" evaluation from world-leading American MNCs. In 1992 Israel went further in its network facilitating policies with the MAGNET program. MAGNET, which stands for Generic Non-Competitive R&D, addresses two problems related to the development and maintenance of the long-term innovative advantage of companies. The first problem is a large number of companies in the same technological space, all of them too small to compete on the basis of, or to advance, cutting-edge infrastructural research activities that are crucial to their survival. The second problem is the underutilization of academic research. MAGNET solves some of these issues by creating a consortium to develop generic technologies. MAGNET consor-

tiums are created for a period of up to three years. All IP outputs are shared among the consortium members, at least one of which must be a university. The consortium members also must agree to license this IP to local companies at a cost that does not reflect monopoly status. MAGNET has been critical in allowing Israeli firms to tap into otherwise inaccessible knowledge domains, and to develop new technologies and products for markets and niches whose needs they did not understand, using technologies they could not afford to develop alone. However, while Israel's sole focus on novel-product R&D and intimate ties with the American industry led it to great success, the economic gains of this success have been very narrowly distributed, and the success of the high-tech industry has resulted in only negligible spillovers to the rest of the business sector (Breznitz 2007a; Breznitz 2007b; Trajtenberg 2001).

Finland is a classic example for the government role as a facilitator using a very different strategy. In Finland, after the fall of the USSR, national employer and labor associations created long ago for collective bargaining and resolution of labor-capital conflicts were infused with a new mission as they morphed into institutions to regulate the transition from a traditional to a high-technology "new" economy (Ornston 2006; Ornston and Rehn 2006). Consensus among the old actors created a platform on which new dense inter-firm networks were built. A panoply of government actions established new public commissions, and agencies pushed the old partners towards agreement on new objectives for the economy and new channels for public expenditure, for example, the Science and Technology Policy Council, which subsequently gave rise to Tekes. These broad agreements legitimized the deep structural transformations involved and formed the bedrock of multi-polar networks on the local level. In the most successful cases of development of new technology industries in Finland, for example in the city of Tampere, new networks were constructed by combinations of previously-developed skilled labor, university strengths, industrial commitment, and municipal leadership. However, Finland's inability to create new companies and its growing reliance on one—Nokia—is apparent even in the case of Tempere, where Nokia is by far the biggest employer (Juba and Sotarauta 2002).

Back to the home court—Lessons Learned

Successful innovation policies throughout the world have taught us a few valuable lessons:

i) innovation policy can significantly enhance economic growth and national competitiveness;

ii) innovation policy are context-specific and need to evolve in tandem with private industry;

iii) there are many different modes of devising and implementing innovation polices, each of which leads to different social and economic outcomes;

iv) to be successful in innovation policy implementation governments need to be able to engage in all three roles: financer, producer, and facilitator.

While far from ensuring success, these points lead to a few principles, which if applied, can increase the chances of success and induce a better policy learning curve. First, the Federal Government should sustain and enhance its important role as financier. While that by itself will not yield a qualitative change, it is necessary as the minimal first step. Second, the government needs to carefully evaluate its R&D production activities to decide which serve useful purposes and which should be restructured or cancelled, and to determine in which domains timely, and perhaps finite (that is limited in time-scope), public production could stimulate large-scale undertaking by private actors, which should always be the ultimate goal of innovation policy. Thirdly, and perhaps most importantly, the Federal Government needs to think more constructively and comprehensively on the role that the government can play as a facilitator of innovation activities. Here scope for experimentation is needed, and while the ARPA/DARPA model has worked in the past it is far from being the only approach that should be pursued.

It is critical to note that in order to conduct the three roles, specifically the facilitating role, a nation must have deep knowledge of the technological domains, as well as a nuanced understanding of the current, and always changing, needs of private actors. This includes knowing and having access to individuals (such as leading researchers in specific labs) as well as organizations, and understanding business dynamics in multiple sectors.

In the case of a the U.S., a big Federal democracy aiming to stimulate growth throughout its economy in all locales, a dual approach, local and Federal, might be the key to success. Creating new Federal-state partnerships could also have the ben-

efit of stimulating states to compete in the development of different, experimental, and creative policies.

From many levels of analysis, American states, in terms of size, economic history and capacity, and unique contextual situation, are similar to many of the European and Asian countries that are widely viewed as the paragons of successful innovation policy experimentation and implementation. Many of these policies necessitate close collaboration among actors within a particular spatial unit, and hence, lend themselves much more easily to state rather than Federal engagement. Furthermore, since many successful innovation policies need to be tailored to specific conditions, both the intimate knowledge essential for the development, and the capacities critical for their implementation, exist on the local and not Federal level.

One way, certainly not the only one, of tapping this potential, creating a dynamic of innovative thinking among policymakers, and devising a working public-private partnership, is to allow for Federal funding to be allocated on competitive basis for states and local governments that develop unique and comprehensive ten to fifteen-year programs that take into account local needs and capabilities as well as the national innovation agenda. Winning proposals should get substantial Federal funding (50–60%), and should be evaluated around the seventh year of the program, by which time the first signs of change should be evident. If successful, these programs should be funded for another finite period of time. In addition the Federal agency responsible for these programs should arrange workshops that allow collaboration and learning among participating states, as well as replication of the more successful models across the country.

We need to recruit the tremendous forces of competition and ingenuity to help us seriously apply innovation to our innovation policies. We must think outside of conventional constraints as we seek to develop policies to enhance the innovativeness of the American business sector and secure our future economic growth.

BIOGRAPHY FOR DAN BREZNITZ

Professor Dan (Danny) Breznitz (Georgia Institute of Technology, Sam Nunn School of International Affairs & The School of Public Policy, Ph.D. MIT) has extensive experience in conducting comparative in-depth research of Rapid-Innovation-Based Industries and their globalization. Dr. Breznitz's first book, *Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland (Yale University Press),* won the 2008 Don K. Price for best book on Science and Technology given by APSA and was a finalist for the 2007 best book of the year award in political science by Fore Word Magazine. His second book (co-authored with Michael Murphree) *The Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China* is forthcoming with Yale University Press in 2010. In addition, his work was published in various journals, as well as chapters in edited volumes. Breznitz is one of five young North American scholars to be selected as a 2008 *Industry Study Fellow* of the Sloan Foundation. Breznitz has also been an advisor for local and national governments on Science Technology and Innovation Policies in the U.S., Asia, and Europe.

During 2006 Breznitz was a visiting scholar at Stanford University's Project on Regions of Innovation and Entrepreneurship, and during 2007 he was a Visiting Fellow at the Bruegel Institute for International Economics, Brussels. His work is sponsored by the Sloan Foundation, the Kauffman Foundation, and the Samuel Neaman Institute for Advance Studies, the Bi-National Science Foundation (U.S. Israel), the NSF, Georgia Research Alliance, and the Enterprise Innovation Institute. In addition, Breznitz is the co-director with John Zysman of UC Berkeley of a collaborative study titled "Can Wealthy Nations Stay Rich in a Rapidly Changing Global Economy?" A former founder and CEO of a small software company, Breznitz is also a research affiliate of MIT's Industrial Performance Center. In addition he is a senior researcher of the Science, Technology, and Innovation Policy Program (STIP) and the Academic Director of the Initiative for Sustainable High Tech Cluster at The Enterprise Innovation Institute (EI2), and the director of the Globalization, Innovation, and Development program at the Center for International Strategy, Technology and Policy (CISTP) in the Sam Nunn School of the Georgia Institute of Technology.

Chairman WU. Thank you very much, Dr. Breznitz.

Mr. Holland, please proceed.

STATEMENT OF MR. PAUL HOLLAND, GENERAL PARTNER, FOUNDATION CAPITAL

Mr. HOLLAND. Chairman Wu, Ranking Member Smith and Members of the Committee, my name is Paul Holland. I am a general partner at Foundation Capital, a venture firm in Menlo Park, California, commonly known as the Silicon Valley. We invest in early-stage companies driving innovation in software, clean tech, the Internet, telecommunications and semiconductors. Since our first fund in 1995, we have invested $1.5 billion in well over 100 innovative startups.

In addition to my responsibilities as a venture investor, I am also a member of the National Venture Capital Association located here in Arlington. The NVCA represents more than 400 venture capital firms and more than 90 percent of the venture industry in the United States by dollar volume.

So let us talk a little bit about innovation. Historically, our government has helped pave the path with policies that encourage innovation at many levels, yet the environment has changed significantly in the last decade and the United States is no longer guaranteed a monopoly on entrepreneurship and innovation.

So I will spend a moment talking about how venture capital works, and I think most of you are probably familiar with this. We take in large pools of capital from endowment funds, universities, foundations, charitable organizations, employee pensions and so forth, and we take our own capital, combine that, and we invest it in hundreds and hundreds of innovative companies over the course of any given year. We do not employ leverage or issue debt as part of our investments, so we are not like a hedge fund or other forms of private equity you might have heard of. We also generally take a seat on the company's board and we work for five to ten years, often reinvesting several times in that company over the course of that time period until we achieve an exit, either an IPO or a mergers and acquisition exit.

The venture class has been recognized for building a significant number of high-tech industries including biotechnology, semiconductors, online retailing and software. Within the last several years, we have invested billions of dollars in clean technology including smart grid, renewable power, power management, recycling, water purification and conservation. In fact, I coordinate the clean tech practice at my firm, Foundation Capital, and I had the honor of giving a nationally televised speech last year with President Obama on clean tech investing, and it was truly a highlight.

My partners and I are extremely proud of the work we do each day and we are working very hard to create a positive future for this country. So what are the results of all this hard work on behalf of venture capitalists and entrepreneurs? Since 1970, companies that were started with venture capital have accounted for $12.1 million jobs, or 11 percent of private sector employment, and also $3 trillion in revenue by 2008. Such companies include historic innovators such as Genentech, Intel, Federal Express, Microsoft, Google, Amgen and Apple. These companies have brought to market thousands of innovations that have improved, and in the case of life sciences, actually saved millions of lives.

So I often get asked why is so much of this happening in the Silicon Valley, and many of you are regular visitors to our region. Forty percent of venture capital in this country is deployed between the cities of San Francisco and San José. There are a number of reasons for that, too long to get into in the time that we have today. We have two outstanding universities there in Stanford and U.C. Berkeley. We leverage those as much as we can. But I think maybe the biggest factor is that we have a very strong risk-taking culture and our society supports it in all the different dimensions including Federal, state and local government. But it is not just Silicon Valley where this is occurring. It is in Boston with MIT, it is in Philadelphia with Penn, Pittsburgh with CMU, Atlanta with Georgia Tech, Duke and University of North Carolina, the research triangle. This is happening across the country and it has been a very, very successful model, particularly over the last 40 years or so.

So that is a look at what is happening on the regional level in our world. Let us take a look at the national level, and the big issue there is competition. Competition is looking internationally like we have never seen before. At the same time we are seeing all sorts of benefits of globalization, and we are big fans of it, we want to see, you know, open standards and open trade provisions from our government. At the same time, there is a significant rise of venture capital and entrepreneurial activity in Asia, Eastern Europe and South America, and foreign governments are being very aggressive in promoting favorable tax policies and improving their infrastructure. So for the first time we have got very, very viable competitors outside of the United States. They are giving us a run for our money.

That is one of the reasons why we support the *America COMPETES Act* of 2007. Some of the major components of that Act are things like support for basic research, so we leverage NIH, DOD, DARPA and ARPA–E, and if we have time later, I will give you some really fun examples of companies that have been started as a result of this that are now employing thousands and thousands of Americans.

Another component of this is support for a highly skilled workforce. This is very critical for us. The venture capital community wholeheartedly supports improving math and science education for U.S. students, particularly in K–12 students, things like STEM curriculum and other fundamentals of 21st century education, some of which I am fortunate enough to see practiced in my children's schools in California at Ormondale and Cormadera and Castalella.

But other critical elements for us are things like immigration reform. Twenty-five percent of venture-backed public companies were founded by immigrant entrepreneurs. We have immigrant entrepreneurs represented at this table. In fact, I would daresay that if you go back a couple of generations, we are all represented in one form or another by immigrants. These companies include stars such as Intel, eBay, Google, Yahoo and Sun, and yet in recent years U.S. immigration policy has become relatively restricted when it comes to bringing in the best and brightest from overseas. We have to stop that and we have to reverse these policies. India

and China are welcoming these bright minds. We have to be first in that regard. For that reason, we are supportive of the Start Up Visa initiatives that are in the House and the Senate. Passage of these types of bills will signal the entrepreneurial community around the world that the United States is indeed open for business.

Another major category for us is access to capital. A significant part for us and a very, very serious near-term threat to our entire industry is what is being contemplated by Congress now in changing the capital gains rate associated with venture capital and innovation. Going back to 1968, Congress passed a watershed law that had risk capital rewarded with a lower capital gains rate, not ordinary income rates. There is a discussion underway right now within Congress to reverse that and to in fact install ordinary income rates on capital gains. If that happens, make no mistake, you are tripling the rates of taxation on our industry and you will absolutely kill the goose that is laying the golden eggs. I can't make that any clearer for you. It is just that simple.

The need for capital, however, does not end with venture investment. We need a lively and a vibration IPO market. Go back to 1996. Sixty percent of the IPOs in the world in 1996 were done in the United States. By 2006, 22 percent were done. Last year, two-thirds of the clean tech exits in clean tech, the field in which I work, were in China, not in the United States. There are a number of things that we have to improve and we have to get stronger around this. The implementation of Sarbanes-Oxley, some of the restrictive provisions around financial regulation are starving our young companies of the ability to have early exits. That is very, very difficult for us. I realize you are not the Finance Committee but we could use your help on that wherever we can.

Finally, on intellectual property protection, we have some of the strongest intellectual property protection in the world but it needs to be even stronger and we need to continue to reform and augment the work of the U.S. Patent Office.

So in conclusion, let us make no mistake about it, the race is ours to lose but to maintain our innovation advantage we must rededicate ourselves to what has made us successful: increasing support for basic R&D, improving math and science education, supporting immigration and patent reform, and improving access to capital through smart tax policies. Without action on these fronts, the United States may find itself in the unfamiliar role of an also-ran in the innovation race. The venture capital community looks forward to working with you, the Federal Government, on this, and I will be happy to take any questions. Thank you.

[The prepared statement of Mr. Holland follows:]

PREPARED STATEMENT OF PAUL HOLLAND

Introduction

Chairman Wu, Ranking Member Smith, and members of the Committee, my name is Paul Holland and I am a general partner at Foundation Capital, a venture capital firm based in Menlo Park, California. Foundation invests in early stage companies that are driving innovation in the areas of software, clean technology, the Internet, telecommunications and semiconductors. We look for new and innovative ideas that don't simply improve the status quo incrementally, but rather disrupt it in positive ways. Specifically, we fund companies that promise to change the way

businesses, consumers and even entire industries behave. Since our first fund in 1995, Foundation has invested more than $1.5 billion dollars into innovative start-up companies located primarily in California but across the United States as well.

In addition to my responsibilities as a venture investor, I am also a member of the National Venture Capital Association (the NVCA) based in Arlington, Virginia. The NVCA represents the interests of more than 400 venture capital firms in the United States. These firms comprise more than 90 percent of the venture industry's capital under management.

It is my privilege to be here today to share with you, on behalf of the venture industry, our perspective on the critical factors that foster innovation on a regional and national basis in the United States. Our country is home to many of the brightest minds on the planet. And that intellectual prowess has benefited our economy in countless ways. Yet we all know that the process of bringing innovation to life is not simple. There is a critical path along which many stakeholders—including entrepreneurs, venture capitalists and policy makers—play important roles. Historically, our government has helped pave that path with policies that encourage innovation on many levels. Yet the environment has changed significantly in the last decade and the United States is no longer guaranteed a monopoly on entrepreneurship and innovation. We have a tremendous opportunity to shape our future and I look forward to discussing today how we can ensure our technological and economic leadership going forward.

The Role of Venture Capital in the Innovation Life Cycle

I would like to share a brief overview of the role of venture capital in the innovation life cycle. For decades, the venture capital industry has dedicated itself to finding the most innovative ideas and bringing those ideas to market. We raise money from institutional investors and our firm partners for the express purpose of identifying and investing in the most promising ideas, entrepreneurs and companies. We only choose those with the potential to grow exponentially with the application of our expertise and venture capital investment. Often these companies are formed from ideas and entrepreneurs doing work in university and government laboratories—or even someone's garage. Many of these ideas would never see the light of day were it not for venture investment.

Once we have identified a promising opportunity, we conduct a thorough due diligence process on the entrepreneur or scientist, the technology on which the opportunity is based, and the potential market. For a venture capitalist to invest in a company, the discovery process must be well underway. Oftentimes, we will delay an investment until further research is successfully completed. Put another way, venture capitalists invest in applied research—not basic research. For those companies that have moved through the basic research process and have a functioning product that passes muster with our firm, we make an investment in exchange for equity ownership in the business. Venture capitalists do not employ leverage or issue debt as a part of our investment. We also generally take a seat on the company's board of directors and work very closely with management to build the company and bring the innovation to market.

The innovation process is long and characterized by significant technological and entrepreneurial risk. We typically hold a venture capital investment in an individual company for at least eight to ten years, often longer and rarely much less. During that time we continue to invest follow-on capital in those companies that are performing well; we cease follow-on investments in companies that do not reach their agreed-upon milestones. Our ultimate goal is what we refer to as an exit—which is when the company is strong enough to either go public on a stock exchange or become acquired by a strategic buyer at a price that ideally exceeds our investment. At that juncture, the venture capitalist "exits" the investment, though the business continues to grow and innovation continues to take place.

The nature of our industry is that many companies do not survive, yet those that succeed do so in major ways. Our asset class has been recognized for building a significant number of high-tech industries, including the biotechnology, semiconductor, online retailing and software sectors. Within the last several years, the venture industry has also committed itself to funding companies in the clean technology arena. This includes renewable energy, power management, recycling, water purification and conservation. Many of the young companies that we fund serve as the de facto R&D pipeline for larger corporations as, in many cases, our start-up technology is far superior than what can be generated in a corporate R&D environment. This phenomenon is especially true in the life sciences and software sectors, where our companies are regularly acquired for their technology and intellectual property. We believe this dynamic will ultimately become the reality in the energy and clean tech

sectors as well. My partners and I are extremely proud of the work that we do each day because we are indeed creating the future.

Historically, venture capital has differentiated the U.S. economy from all others across the globe in terms of job creation and innovation. According to a 2009 study conducted by the econometrics firm IHS Global Insight, companies that were started with venture capital since 1970 accounted for 12.1 million jobs (or 11 percent of private sector employment) and $2.9 trillion in revenues in the United States in 2008. Such companies include historic innovators such as Genentech, Intel, FedEx, Microsoft, Google, Amgen and Apple. These companies have brought to market thousands of innovations that have improved and, in the case of the life sciences sector, actually saved millions of lives.

Venture-backed companies are responsible for the introduction of Internet navigation and search, microprocessors and wireless applications. On the medical side, our companies brought to market drugs to treat cancer, diabetes, heart disease and spinal chord injuries. And on the clean technology side, we are actively working on innovations to reduce our dependence on foreign oil and create a more sustainable environment for the next generation. It is almost inconceivable that these monumental advances were once small ideas tucked away in a lab or a living room. But we assert that the next great innovation is today a small idea waiting somewhere. We are committed—along with the government—to finding and funding it. Our country's future depends on it.

The Silicon Valley Phenomenon

No other region in the country can attest to the positive impact of innovation on the economy than California. In fact, most people who are familiar with venture capital—even remotely—tend to associate it with Silicon Valley. It is indeed the industry's Fertile Crescent, with approximately 40 percent of all venture capital dollars invested in companies from San Jose to San Francisco. For this reason, VCs are often asked what factors drive Silicon Valley's ongoing growth and keep the region successful in fostering innovation and growing new companies. It is a relevant question because the answer offers a blueprint for other regions that wish to emulate the Valley's success. This blueprint is also consistent with what our country must do as a whole to keep innovation alive.

Like Silicon Valley, most successful venture capital hubs begin as communities of extremely bright, best-in-class innovators. These innovators are usually drawn together by a top-flight research university, government laboratory or a highly innovative, often venture-backed company. Stanford University has been the source of countless innovations around which venture capitalists have formed Silicon Valley-based companies. The same can be said for MIT in Boston, University of Pennsylvania in Philadelphia and Duke and North Carolina in the Research Triangle region. Silicon Valley is also home to important anchor companies: Intel, Genentech, Cisco and Google are just a few. These companies regularly spin-out new entrepreneurs who pursue their own ideas and start-ups from existing operations. They also foster a pool of technical talent available to the region. We have seen similar types of spin-out companies in places such as Austin, Texas with Dell, in Minneapolis with MedTronic, and in Seattle with Microsoft.

Often, these communities coalesce around a certain industry or technological niche. Silicon Valley has a long and successful history of embracing these niches early on, beginning with semiconductors and following up with biotechnology, enterprise software, consumer Internet and now, clean technology. Other examples of regions that have successfully built an ecosystem around a specific technology include New York with new media, Tennessee with healthcare IT, and Northern Virginia with telecommunications. Concentrating on these niches creates a virtuous circle that spurs research and innovation, draws more talent and attracts more capital to the region. And while regions such as Silicon Valley and Boston account for a majority of the investment in certain sectors, there is room for more than one region to claim space. To wit, Florida, in its quest to become a life sciences center, recruited the new Scripps Institute to locate there and has benefited from that institution's presence in Palm Beach County. Many regions are now vying for a stake in the clean technology sector. Rocky Mountain states like New Mexico, Colorado and Arizona making strides in this area.

Innovators become entrepreneurs only when they have the supporting environment to do so. Venture capital alone is not enough. There must be a sound mechanism for transferring technological innovations from the research institutions and scientists that spurred them to the company that will guide them to market. To support that process, a robust network of lawyers, accountants and other business professionals to help with business planning, networking, intellectual property protec-

tion, IPO registration compliance and hiring issues is also important. In addition, though as simple as it sounds, the region must have an infrastructure that can support growing companies. That means efficient local and regional transportation systems, convenient airports, affordable housing, quality schools and vibrant cultural and social scenes.

Government and civic support is also essential. This starts with favorable tax policies, common-sense regulatory structures and encouragement of basic research. State and local initiatives that reward emerging growth companies also make a significant difference. Please understand that is different than giving massive tax abatements to large local corporations. Instead, a program like Ben Franklin Technology Partners in Pennsylvania, that supports start-up companies in their earliest stages, helps create a pipeline from which venture capitalists can draw. Also, state pension funds that invest in local venture capital firms also drive success. States such as California, Pennsylvania, and Wisconsin have strongly supported local venture firms in recent years, resulting in increased investment by indigenous firms in their states' start ups.

It is important to note that venture capitalists do not create these conditions favorable to investment. We seek them out. For those looking to replicate Silicon Valley's success, it starts with these factors and builds from there. States should understand that growing such an environment is an expensive, long-term endeavor. However, I'm sure that Californians will tell you that the economic pay-off is worth it.

Looking Forward on a National Level

The ingredients that make for successful venture capital hubs like Silicon Valley are not unlike the ingredients for a thriving innovation ecosystem in the U.S. as a whole. Access to strong basic research, the best and brightest minds, public policy that promotes access to capital, and an infrastructure that supports the entrepreneur are in fact the precise components that have historically allowed the U.S. to thrive on the innovation spectrum. And these same drivers will determine our fate going forward.

Yet, it is important to recognize that the global environment for innovation has changed dramatically in the last decade—creating both opportunities and threats to U.S. innovation. Technology has indeed made the world flat and our companies today all employ global strategies when it comes to markets, product development and operations. The global markets offer our companies tremendous growth opportunities—provided the U.S. maintains open trade provisions. Yet, at the same time, there has been a significant rise of venture capital and entrepreneurial activity in regions outside the United States such as Asia, Eastern Europe and South America. As entrepreneurialism grows on a global scale, we face a new competitive environment in which innovation can be developed anywhere. Foreign governments are being extremely aggressive in promoting favorable tax policies, improving their legal, accounting and intellectual property structures, and boosting their R&D spending to foster more innovation in their countries. The U.S. needs not only to maintain our current commitment to an innovation agenda but rise up to meet the challenge set by our foreign competitors or risk losing our technological edge.

For these reasons, the venture capital industry supported the America Competes Act and continues to support the spirit in which it was passed in 2007. In order for the U.S. to maintain its competitive advantage and economic leadership, we must continue to aggressively promote a public policy agenda that rewards risk takers and embraces innovation at a national level. Components that are particularly relevant to the venture capital industry and our role as purveyors of innovation are as follows:

Support for Basic Research

The government has a critical role to play in the area of basic research. It is from this pipeline of scientific advances in fields such as information technology, life sciences and now, clean technology, that the venture capital industry has traditionally drawn many of our innovations. Often, early stage research into new discoveries is first funded with Federal dollars in a university or government lab and then commercialized by a venture investor.

Such was the case with Atheros Communications, founded by leading experts in radio and signal processing at Stanford University. Atheros benefited early on from access to DARPA research on semiconductors and communications. My firm helped to shepherd the researchers out of Stanford and invested the first $100,000 into the company in 1997. Since that time, the company has become the leading provider of WiFi communications, providing the technology that powers innovations such as wireless local area networks (WLAN), mobile WLAN, global positioning systems

(GPS), Bluetooth, Ethernet and powerline communications. Atheros went public in 2004 and today employs more than 1,300 people and has a market capitalization of $2.5 billion.

Sources of these basic research funds have historically included the NIH, DOD, DARPA and, most recently ARPA–E. Continuing to support federally funded research through these agencies will allow the symbiotic relationship between the government and venture capital to continue. Essentially we pick up where government funding leaves off. We believe this relationship will be especially important in the area of clean tech innovation. We have been very encouraged by the funding of ARPA–E at the $400 million level. We hope to see a continued commitment at that level or above going forward, so that the exciting work taking place in those labs has the opportunity to be brought to the American public. We also ask that policy makers continue to exhibit the same patience they have shown in the past for the high-risk and long-term nature of the innovation process. This support is critical to our ability to see our projects through to success.

Support for a Highly Skilled Work Force

In addition to supporting the research, government must also support the entrepreneurial and technological talent that brings this research to life. The venture capital community wholeheartedly supports improving math and science education for U.S. students, particularly in grades K through 12. Other countries have been committed to the Science, Technology, Engineering and Math (STEM) components of education for some time. Our understanding is that we are making strides in these areas; but we can not ease up on our commitment to engage our students more fully.

In addition to better educating our own students, it is also critical that we ensure that the best and the brightest scientists and entrepreneurs from all over the world want to come to the United States to innovate and grow their businesses. The venture industry has long supported highly skilled immigration reform that would make it easier for foreign born nationals to build companies in the United States. The NVCA-commissioned study, American Made: The Impact of Immigrant Entrepreneurs and Professionals on U.S. Competitiveness found that 25 percent of venture-backed public companies were founded by immigrant entrepreneurs. These companies include innovation stars such as Intel, eBay, Google, Yahoo and Sun.

Yet in recent years, U.S. immigration policy has become restrictive relative to the policies of foreign countries—and just when they are proactively growing their own entrepreneurial and innovation ecosystems. As the United States is making it more difficult for foreign scientists and entrepreneurs to enter our country, other countries such as India and China are welcoming these bright minds to their shores. Unless we see a significant change in immigration policy for highly skilled workers, we risk losing the brightest talent to our global competitors.

For this reason, we are very supportive of the Start Up Visa initiatives that have been introduced in both the House and the Senate. Under these bills, immigrant entrepreneurs can obtain a special visa to build their companies in the United States if they have secured venture capital financing from a qualified investor. The passage of such a bill would send a much needed signal to entrepreneurs around the world that United States wants them innovating here. Companies that are formed here drive innovation here. There is no other way to say it.

Access to Capital

Support for innovation also hinges upon the government's understanding of the importance of capital formation and support for incentives for long-term investment and risk taking. While we know that this committee does not have jurisdiction on developing tax policies, it is an area that remains of critical concern to the venture industry and has the potential to impact our ability to fund innovation. Entrepreneurs and venture capitalists must continue to be rewarded for the risks they take. Today there is a meaningful differential between ordinary income and capital gains tax rates, which offers an incentive for the long-term investment in innovative companies as opposed to short-term speculation. Without this differential, the reward for building and growing a company from scratch is significantly lower and less likely to promote this type of activity.

We also continue to support the current tax policy that allows both entrepreneurs and the venture capitalists who invest their time and capital alongside management to receive capital gains tax treatment when they have successfully built and grown companies. This policy—which grants capital gains tax status to venture capitalists who successfully invest in and help companies to grow—has been under fire as certain lawmakers have sought to change the tax status of carried interest to ordinary

income. The result will likely be a long-term reduction of venture capitalists, a lower risk threshold for existing venture capitalists, and fewer innovations funded overall. By enacting this policy, Congress will put innovation and job creation at tremendous risk. Our position on this issue is publicly available from previous hearings and we continue to welcome the opportunity to work with lawmakers to better understand the implications of this troubling proposal.

The need for capital does not end with venture investment. The goal of many venture-backed companies is to one day thrive as a publicly traded entity. However, the last decade, and the last three years in particular, have been especially hard for venture-backed IPOs. A healthy venture-backed IPO market would see close to 100 new issues each year. In 2008, we saw just 6 venture-backed IPOs; 2009 had 12; in the first three months of 2010, there have been just 5.

While much of this lackluster environment can be attributed to the financial crisis and skittish investors, we believe that there are fundamental structural issues that need to be more closely examined. The implementation of Sarbanes Oxley, the separation of research and investment banking, and decimalization—among other factors—have all contributed to a market that is not receptive to small cap IPOs. This situation is critical to the future of innovation because without an IPO market recovery, venture capitalists are not in a position to make new investments at the pace we have kept in previous years. We will spend more time with existing companies, wait longer to take them public, and complete fewer new deals. We do not want these good companies to wither on the vine if we can jump start the IPO market once again.

We believe there is a role for policy makers and regulators to better support emerging growth companies and commit formal resources to understanding the dynamics and challenges of today's IPO market. Dedicating senior SEC officials to address the collective interest of these rising stars will send a message to the market that the government is there to help, not hinder, their growth and innovation. We believe the formation of such a group would be extremely well received and we as an industry would commit to supporting its endeavors.

Intellectual Property Protection

The U.S. must also enact some essential reforms to its patent system. Few systems have protected and rewarded innovation better, but the system has gone 50 years without so much as a tune up. Patents are particularly important to the start-up community because they are sometimes the only asset of value that an emerging company holds. Often venture capitalists evaluate the quality of a company's patent or patents when deciding whether or not to invest. Thus, patents protect the value of both the innovation and the investment.

For this reason, the U.S. must focus on improving the quality of the patents it grants and the predictability of its protection process. Stronger patents will help reduce the amount of needless litigation generated by specious or spurious challenges and infringement claims. Greater predictability in how the U.S. Patent and Trademark Office, or PTO, awards and protects patents will also reduce risk for emerging companies and their investors. Current patent reform legislation moving through the Senate addresses many of these challenges and we are hopeful that the final outcome will institute reform that adequately funds the PTO and protects small innovative companies.

Conclusion

As we've seen, the United States has harnessed innovation to power economic growth, raise standards of living and improve our lives. The Federal Government has played a vital role in this success through innovation-friendly policies and incentives. We applaud policy makers who seek to foster an ecosystem where risk taking and entrepreneurship are rewarded. Yet the bar continues to rise as many foreign governments have begun to emulate our success and seek to surpass it. Their successes mean that we no longer hold a monopoly on innovation and its benefits.

Make no mistake: The race is still ours to lose. But to maintain our innovation advantage, we must rededicate ourselves to what made us successful: increasing support for basic R&D, improving math and science education, supporting immigration and patent reform, and improving access to capital through smart tax policies. Without action on these fronts, the United States may find itself in the unfamiliar role of also-ran in the innovation race. The venture capital community remains committed to doing our part to ensure this is not the case. We look forward to working with Members of this Committee, Congress and the Administration to support the best and brightest ideas and continue to fill a robust pipeline of innovation for our

country. I want to personally thank you for the opportunity to discuss these important issues with you today and I am happy to answer any questions.

BIOGRAPHY FOR PAUL HOLLAND

In addition to coordinating the CleanTech practice at Foundation Capital, Paul's primary focus is on helping early-stage start-ups go from zero to $100M in revenue. He helped take public two venture-funded software start-ups, Kana Communications (KANA), and Pure Software (RATL). Paul currently serves on the board of directors for Bella Pictures, CalStar Products, Chegg, Coverity, Ketera, Serious Materials, and TuVox; and previously for Talking Blocks (acquired by Hewlett-Packard) and RouteScience (acquired by Avaya).

Prior to joining Foundation Capital, was senior vice president of worldwide sales at Kana Communications, a leading supplier of Enterprise Relationship Management solutions to strategic e-businesses. Paul went on to build a team of over 350 people that secured more than 900 customers worldwide, helping Kana become one of the top ten IPOs of 1999. Before Kana, Paul was a vice president and general manager for another highly successful start-up, Pure Software, helping raise their market value from $2 million to over $1 billion in his five-year tenure there. He began his professional career at SRI International (formerly the Stanford Research Institute).

Paul enjoys spending time with his wife Linda Yates, and their three daughters, Kylie, Devon, and Piper. In his spare time he enjoys golf, volleyball, poker, traveling (he has visited over 50 countries to date), and is building a LEED Platinum home in Portola Valley. Paul has been guest lecturer on entrepreneurship at Dartmouth's Amos Tuck School of Business, Harvard Business School, James Madison University, and the Stanford Graduate School of Engineering. He is an active advisor and supporter of Project BUILD in East Palo Alto, the Bing School at Stanford and Sustainable Silicon Valley. Paul received an MBA from the University of California at Berkeley; an MA in Foreign Affairs from the University of Virginia; and a BS from James Madison University.

Chairman WU. Thank you very much, Mr. Holland. At this point we will open for our first round of questions, and the Chair recognizes himself for 5 minutes.

I just want to point out that we have a number of opportunities right before us. It is not just the Administration's deployment of broadband but the Administration already has statutory approval and funding for health IT initiatives, for its energy initiatives. We have a couple of very important legislative opportunities in front of this Congress. One is the reauthorization of SBIR and of course the big one is the reauthorization of America COMPETES, which affects so much of what you all have addressed.

I am going to begin by throwing you a puffball for you all, and I think I will just go from my left to right and ask that you, from your view, don't repeat anything that is cited to your right but list additional factors, and the question is, what are the biggest barriers, what are the biggest barriers to entrepreneurship and what are your top one, two or three priorities, priority recommendations to help address those particular barriers. Mr. Chopra, why don't we start with you?

Hon. CHOPRA. We are squarely focused on strengthening the commercialization success rate out of research and development investments as a Nation, and you heard a terrific body of testimony from Dr. Kamlet. But Secretary Locke is leading a dialog with the university community throughout the country specifically on how we address this issue. I will simply highlight one basic phenomenon. As my mentor describes, we have a terrific portfolio of ideas throughout our university system and we have a challenge to bring market relevance to those ideas. In combination we can achieve a much higher rate of entrepreneurship, and so a great

deal of the reason you saw the $12 million investment in the partnership for innovation fund in the National Science Foundation in the President's budget—was to bring more of the market relevance capabilities to the ideas that are coming out of our universities. You see that our innovation clusters work, and we are going to continue to focus on that as an important lever to see, we think, an improvement in the rate of entrepreneurship in the country. Obviously the factors I had cited earlier-about ensuring the conditions for an open and competitive marketplace, the capital markets success, an open and efficient government—are all factors as well but we are first and foremost going to look at the commercialization aspect.

Chairman WU. Terrific. Thank you.

Dr. Kamlet.

Dr. KAMLET. Thank you. I will focus on one that is specific to universities and in particular to university-industry partnerships. Right now a company may come to the university and to a faculty member and say I would like to give you $1 million to do research in this particular area, and the faculty member will say that is fabulous, that is exactly what I want to do and this is going to be critically important research, and then we tell the company but you do know that you will not own the intellectual property, that we can't guarantee that we will license it to you and we cannot guarantee we won't license it to your competitors instead. And then the company says I am sorry, you must have misunderstood, I said we were going to give you $1 million. And we say yes, we heard you correctly but those are the conditions, and then the company says here we go to Singapore. And this is a reflection of an unintended aspect of the tax laws pertaining to doing research that is funded by industry in buildings that were originally once upon a time financed by tax-exempt bonds. It seems like it is a small thing but when you are trying to find good ways to interface with industry, it is a huge impediment and we would be happy to provide more details about that. It is something that is not recognized very broadly but affects us quite a bit.

Chairman WU. You know, a staffer brought that to my attention about five years ago, and I had a hard time understanding it until just this moment. Thank you.

Dr. Atkinson.

Dr. ATKINSON. Let me list two, one that isn't this Committee's jurisdiction but I do think it is a central one, and that is what you could term foreign technology protectionism or mercantilism. I think it is much harder for entrepreneurs to succeed in this country now when you have intellectual property theft on a rampant basis, when you have standards manipulation, when you have a whole set of other practices that countries, not just China, but other countries are engaged in that that violate the spirit and oftentimes the law of WTO. I think that is a key factor that we are going to have get right.

But the second thing I think is, we don't do anywhere near as good a job of creating support systems for entrepreneurs at the ground level, and you compare that to a country like Finland which has a wonderful support system linked to their universities where if you are an entrepreneur with an idea, you can get help, you can

get technical assistance, you can find maybe an incubator to be in. You can get easy technology transfer from universities. So I commend what the Administration has done and I hope we can continue to improve on that because I think that is the right direction to go as we have got to beef up these regional innovation clusters. I think that would be an important step.

Chairman WU. Thank you. Dr. Breznitz.

Dr. BREZNITZ. I would like to follow Dr. Atkinson and the Honorable Chopra and also to talk about people, and in this case with great opportunity we have with this financial crisis that we just had. If you look at other countries, Finland, Israel and Ireland, one of the most important things for the high-tech industry was a crisis after which there were released a resource of a great genius who are in their middle ages with families and kids that need to go to college that couldn't even think about becoming entrepreneurs before and now they had to, and what those countries did is help those kinds of people who know the industry, know how to make products but never wanted to do this job, now had to do this job, helped them to get the education to be entrepreneurs and the environment to be entrepreneurs and I think that is part of what we should do.

Chairman WU. Thank you.

Mr. Holland.

Mr. HOLLAND. I will try not to be duplicative. I got the bad seat for that. It is pretty straightforward from our perspective.

Chairman WU. Well, I knew that you were up to the challenge.

Mr. HOLLAND. Thank you so much, Chairman. I appreciate your confidence.

So straightforward for us. Please don't triple the tax rate on the industry that has created 11 percent of the high-quality jobs and about 20 percent of the GDP in this country over the last 40 years. It is pretty straightforward from our perspective. Second, pass the Start Up Visa Act and take any steps necessary to ensure that the best and brightest from around the world continue to come to this country and don't choose instead to go to China and India and other places that welcome them in a more receptive way than it looks as if we are about to as a society.

And finally, continue to drive for improvements in math and science education and a 21st century curriculum in our K–12 system. If any of you saw the recent Friedman article on the Intel Prize, which the top science students in the country compete for, 80 percent of the kids that were there were either first- or second-generation immigrants and many of whom's parents had had training elsewhere. We have got to upgrade our basic infrastructure in K–12 and get back on the forefront of producing the best scientists in the world.

Chairman WU. Thank you very much.

Mr. Adrian Smith of Nebraska, five minutes.

Mr. SMITH. Thank you, Mr. Chairman, and thank you to the panel for sharing your expertise. I am grateful for the many perspectives that you bring and certainly I hope that we can focus on innovation more so every day. I can't help but think that the best driver for more innovation is available capital, and so I want—and I think we need to be mindful of that. I understand the government

needs to provide a nudge here and there but I struggle to think where the government should be the most important driver of innovation because I think that the private sector is underestimated with that. This has been interesting hearing the various perspectives and so again I just want to reiterate how much I appreciate your willingness to come here today.

Dr. Chopra—I hope I am pronouncing that right—how involved should the Federal Government be in terms of the growth of innovation and what are the building blocks that you mentioned only the Federal Government can provide?

Hon. CHOPRA. Well, thank you for the question. We actually strongly agree with the view that our private sector has been at the heart of job creation and the success of our entrepreneurial economy. But we, as I referenced in testimony, believe that there is a balance to be struck around building blocks, and the building blocks in particular are very straightforward, basic research and development, the work this Committee had done on putting us on track to doubling the basic research investments at NIST, the National Science Foundation and the basic science office within the Department of Energy. We very much believe in the importance of basic research investments and that is why the President has done as much as he can both in the stimulus act and in the proposed budget-to get us on track for the investment.

On the workforce piece: I think, to underscore Mr. Holland, we are absolutely committed to making sure that our educational system focuses on science, technology, engineering and mathematics. That is why in the Race to the Top Fund, the only competitive differentiator a state could get extra points for when they applied for the Race to the Top funding was the degree to which they incorporated STEM into their application. It is the only differentiator. That is why the President, with basically no government money, collaborated with dozens of companies to create the Educate to Innovate Initiative which has already tallied over $500 million in private sector and philanthropic commitments to focus on STEM education. His priority goal is having America achieve the highest proportion of college graduates in the world by 2020, all of that is an essential building block. But we also believe in advanced IT infrastructure and the degree to which we have effective and efficient broadband, affordable and universal broadband throughout the country is a key priority for this Administration. If you are in a rural part of the country and you have a terrific idea and you want to build that application to generate wealth in your neighborhood, with the access to high-speed affordable broadband, we think you deserve every right to have the ability to compete. So those are the key building blocks as we see them, and I would be happy to go into more detail if you would like.

Mr. SMITH. So I hear you saying that perhaps research wasn't exactly ignored during the tech bubble, 1995 to 2000 or 2000 to 2007. I think you mentioned previously that it was ignored. Really? I mean, do you really mean that?

Hon. CHOPRA. Maybe I misunderstood your characterization. I never said that research and development investments per se had been ignored, but I think if you looked at the overall performance, the statistics that Rob Atkinson cited very clearly were that there

is a distinction between flat year after year, or I should say consistent with historical purposes, and how others around the world are competing. I think Rob's statement that we had been at the top on a range of these measures and that if you look at the rate at which we have improved on those numbers from 2000 to 2009 that the rate of change in our investments in these areas hadn't kept up the pace. I think that is the heart of the COMPETES Act, about putting us on track to doubling R&D. It is not that per se the numbers had fallen and we have ignored them. We have been funding universities forever. But it is the notion that we hadn't put more of the research emphasis in that area, and I think that was where I was referring to, the notion of the historical perspective.

Mr. SMITH. Okay. Thank you. I appreciate that. I do want to also add, you know, as I am across not only my district but I do get out of Washington and my district now and then, there is an immense concern that some of the goings-on in Washington will indeed stifle innovation, whether it is tax policy as has been mentioned a little bit here, and I don't want to elaborate in the interest of time on exactly what these things are, but I want to give emphasis and pass along the concern of many Americans that many of these policies, tax policy among them but just one of them, would constrain innovation, would have a lockdown among our economy that is especially damaging, especially to innovation, especially to technology, ultimately to prosperity, and as we know, our budget relies heavily on those who have prospered and the fewer prosperous folks and entities we have, the more our budget hurts.

And so I know that my time is up and so I want to close with that, at least for now, but again, let me say thank you for your expertise.

Chairman WU. Thank you very much, Mr. Smith.

Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to all of our witnesses. As is always the case whenever we are in this Subcommittee, we hear much more interesting and creative things than in some other places here in Congress, so thank you.

I want to ask about this notion of innovation and entrepreneurship because I do think that there is a distinction and I think sometimes we get confused that merely investing in entrepreneurship is investing in innovation, and I wonder if some of our witnesses could actually discuss that, and along those lines, also this notion of investing in risk taking and the role of government, particularly in early stages in risk taking which might be distinct from the kind of risk taking, Mr. Holland, that you spoke about, where you are making decisions about where to place venture capital. And perhaps starting with Mr. Chopra, Mr. Holland, I wonder if you could weigh in on that.

Hon. CHOPRA. Very thoughtful questions. Thank you. Let me begin by saying the distinction between innovation and entrepreneurship may be slightly less broad if you focus on high-growth entrepreneurship, and a great deal of our policy framework is focused on high growth, and of course, neither are sufficient. Simply investing in high growth, one has to make some leaps of faith as to what is in fact a high-growth business, and there is a whole body of work

around how one does that. Experts like Paul at the end are focused there.

On the topic of risk capital, we see that the President has made investment decisions to reflect this, that high-risk, high-reward basic research should remain a priority within the government. So while we have asked for the rate of growth to continue to rise in investments in National Science Foundation and so forth, we are also innovating within how that money is deployed so that we are pushing as much as we can to ensure that those programs that they fund allow for creativity and innovation. That is what I would call the productivity with which our R&D investments flourish, and I think high-risk, high-reward opportunities that we are focused on-for a specific example, ARPA–E in the energy domain—allow us to take a chance in areas that may not be as viable for traditional private investment but might make sense given the construct of where we are from a basic research perspective.

When it comes to risk capital in the commercial setting, as we said earlier, creating the right market conditions that spur productive entrepreneurship is where we have focused our policy priorities. So making sure that we are doing what we can to be supportive of our private sector participants and ensuring that we are doing what we can to make government work, where we engage, that we have created a capital markets environment that is supportive and encouraging of the kind of investments that——

Ms. EDWARDS. Well, can you tell me how that relates to the new rules around—the new policies around SBIR? Because we have heard testimony in our larger subcommittee and this Committee about the tensions between the sort of private smaller business entrepreneurs and the institutional-based educational research institutions.

Hon. CHOPRA. Well, actually I think there is a great deal of creativity and innovation taking place. I wouldn't call it matchmaking—that may not be the right word—but just last week the National Science Foundation announced a $4 million solicitation, kind of a matchmaking service, to find the most innovative SBIR firms coupled with the most successful engineering research centers to see if they could collaborate together in spurring new economic activity. So we are focused. I think the comment that I was making about SBIR was, DARPA as just one agency has tried to streamline it. You know, one of the things that is frustrating, if you are a small business and you are successful in winning an award but you have to wait six months to get a contract, you can't carry your cash flow for that long. It is almost not worth the effort. So by getting them to streamline the operations and say well, in 60 days we are going to get you paid to get you to work, we think that is more in line with the notion of a small business. So there are some operational aspects to this that we are trying to get right.

Ms. EDWARDS. Before I run out, Mr. Holland.

Mr. HOLLAND. Yes. Thank you. It is an honor to take a question from you, Representative Edwards. I was born in Baltimore a long time ago, so I am very proud of my birth State of Maryland.

I think, simply put, when Steve Jobs and Steve Wozniak were forming Apple, when Gordon Moore and Bob Norris were forming Intel, when Serge and Larry were forming Google, to put it bluntly,

they didn't give a frog's fat behind about what was going on back here in Washington. It just doesn't work that way in entrepreneurial circles. We just do what we do. It is almost as if the entrepreneurs are almost genetically programmed to start companies and to raise capital and to hire people. It is just the way they exist. It is like artists who create art. It is like writers who write. It is a form of existence that people do.

Where government can help is in the areas that Dr. Chopra is referring to. Interfering in the way that capital is formed and capital is deployed and making it less efficient for that capital to be deployed is an incredible hindrance. That is the hallmark of Second World countries. That is not a hallmark of this country. And so that is one of the things that we are very, very concerned about as we look at what happens. So we have plenty of private capital available to help start these companies and get things to happen. Just putting us in a position where we can go and operate and do what we do and enable entrepreneurs is all we ask of the Federal Government at that level. All the work that we are hearing about here with the universities, the national labs and so forth is very, very important but we deal with things at the end of the line. We are where the rubber meets the road in trying to make these into businesses that will hire millions and millions of people. We know how to do that. The industry knows how to do it. But we are at risk right now.

And just as a footnote, just to give you an idea, there were 1,200 firms practicing venture capital by the year 2000. There are probably close to something like 600 or 700 firms now. Only 95 of those, according to some sources, did more than four investments last year. That is a very scary statistic for anybody that thinks about job growth over the next five or ten years. And if you add on to that some of the things that are being contemplated, that is only going to get worse.

Ms. EDWARDS. Mr. Chairman, I have greatly exceeded my time.

Chairman WU. Mr. Smith, five minutes.

Mr. SMITH. I would yield if the Member from Maryland wishes for any more time. If she is on a roll, I don't want to stand in the way. Okay. Thank you.

Now, we have heard here this morning that America is one of the only countries in the world that does not have a national competitiveness strategy yet the Committee is continually examining our innovation and competitiveness needs through various hearings, culminating in the passage of the 2007 *America COMPETES Act* and continuing with its legislation reauthorization this year. To all the witnesses, what do you see as the failures in the current America COMPETES that would lead to perhaps such a conclusion?

Dr. ATKINSON. Let me start. I can't resist the last question so let me do 30 seconds on that, because I think one of the problems with our innovation policy is, we are torn between, is this something the private sector does or is it something the government does. And with all due to respect to Mr. Holland's last comment, when you look at many of the Silicon Valley companies, they can trace their roots very clearly back to government funding in one way, shape or form. Google had an NSF grant and others had NSF grants around library technology, searching technology. Intel, one of its

first customers was the Defense Department. In fact, in 1992, the county in the United States that had the most defense contracts—this was a study I did for OTA [Office of Technology Assessment] when OTA still existed—was actually Santa Clara County. So it is sort of I think a false choice to say it is all entrepreneurs who are creative and it is all the government—the government didn't create Apple nor could it, but certainly it helped, and I think we have got to think about our policies in that regard.

So to your point about COMPETES, we are big supporters of COMPETES. I think it was a very important first step. But COMPETES is a little different than a strategy. COMPETES is a set of policies and programs, and I think what we would argue needs to be framed on that is a very in-depth strategy to really look at exactly where our weaknesses are, where our strengths are. And the last point on COMPETES, and I would echo Dr. Breznitz's point, I think we need innovation in our innovation policy. I think COMPETES was principally about what economists would call supporting factor conditions, in other words, more basic research and more STEM personnel. Those are very important, and we have not done enough of that in this country. But there is a whole set of other things around tax policy, around institutional frameworks, what Mr. Chopra was talking about, public-private partnerships, research consortia, better university relations with entrepreneurs and companies, and I think that is where the next COMPETES could do a little more with.

Dr. BREZNITZ. If I can add, I can also tell something about what other nations are doing since I have done this for both Finland and Israel and other nations do every seven years in the case of Finland, which I think is the Nation that does it, convey a group of experts, both local and foreign so they know they have somebody to evaluate them, and try to really look at how the country works, what are the policies and do they make sense together, not just as one act but all the tax laws, all the education facilities, all the entrepreneurship policies, do they make sense together? How they can be fixed? What are good ideas to fix them? And that I think is what put both Israel and Finland from peripheral economies—let us call them that—to being on the forefront, and I think that this is what we should do. So I do think that we need to, as Dr. Atkinson said, think strategically about those issues.

Mr. HOLLAND. And if I could just tag onto Dr. Atkinson's comments, I certainly don't mean to give the impression that we don't appreciate some of the groundbreaking work that has been done over the years from the Federal Government in the Silicon Valley. In fact, I will give you an example out of portfolio. There is a company. I will mention the name of the company. It is Atheros Communications. I am going to guess that perhaps some of the people on this panel would know but most of the people in the public won't know Atheros. When I tell you what they do, you will all know. This is a company that was funded, we funded it with $100,000 in 1997. There was a professor named Theresa Mung, first-generation Chinese, Ph.D. at Stanford University, and she had come up with an innovation in communications and we brought her into our group. We brought her whole lab over into our building. I will fast forward this. Eighty million dollars of private investment

later including some really interesting work early on with DARPA, and this company is now the inventor of what is now known as WiFi, so most of us now in our personal computers, when we fire up our personal computer, there is a wireless chip in it and it is almost guaranteed it is by this company called Atheros. The company is worth several billion dollars and employs close to 10,000 people. It integrates all the different things that we are talking about here today. I think that point that Dr. Breznitz is making about, I will describe that as a holistic and an integrated strategy. I think that is often really hard to do in this country but it is worth it in this case if we can find a way to do that.

Mr. SMITH. Anyone else? If not, thank you.

Chairman WU. Thank you very much.

The gentleman from New Mexico, Mr. Luján, for five minutes.

Mr. LUJÁN. Mr. Chairman, thank you very much. I appreciate very much the conversation today and the emphasis on R&D, the emphasis with commercialization, but I am very concerned of the lack of mention of our national laboratories when we talk about commercialization, tech transfer, trying to understand what is not working there with legislation that has been brought forth in the past to create an environment such that tech can transfer and we can commercialize it, but we do know that we don't see much of it. Back in the 1990s, we saw an acceleration that created the cooperative research and development agreements with lack of utilization going into 2000 and 2001, and we need to figure out how to integrate them more into this and see how we can involve them.

Dr. Atkinson, I very much appreciate that you did mention the national laboratories with your bullets that you highlighted. The one thing that I would ask is your perspective on how we can use our national laboratories as part of the nucleus for the regional innovation clusters. As we all know, the national labs currently engage in a range of tech transfer activities but we still don't see that strength, and you highlight with your first bullet to see what we can do to remove the restrictions on universities from having specific commercialization objective. I wonder what your thoughts are around that, and also, Mr. Chopra, around what we could do with creating incentives so that we can see more commercialization and this kind of activity and even incentives for entrepreneurial lead so that way we can create certainty for companies that Mr. Holland would bring in, the scientists, the engineers, the physicists that help develop these ideas is able to partner with those entrepreneurs that have the ability to manufacture, and your thoughts on that.

Dr. ATKINSON. Excellent question and comment. We did a report last year with a colleague of ours at University of California Davis, Fred Bloch, and Fred did a report called "Where Do U.S. Innovations Come From," and he did an analysis over 40 years with the top hundred innovations every year. What Fred and his team found was that Federal labs actually play a more important role than you think, that about two-thirds of award-winning innovations today, actually more than that, about 75 percent, come from collaborative partnerships. That is very different than 30 years ago when most innovations came from one company having it in their lab, figuring out how to do it and commercializing it. Today it is much more

about collaboration—SBIR award winners, Federal laboratories, universities, small businesses, big businesses. So in that new ecosystem, Federal labs can play an important role. And we see that in New Mexico, for example, the Sandia Science Park, very effective. There is an innovative approach to try to get some of those technologies out of there.

I think we could do two things. One, in the 2005 energy bill, there was a provision put in there by Senator Bingaman, I believe Senator Domenici at the time, on a collaborative energy R&D tax credit so if you worked with a Federal laboratory, you are a company and you worked with a Federal laboratory on energy R&D, you could get a more generous credit because the logic is, a lot of that benefit is going to spill over. A scientist at the lab will publish those results. I think we could just change that provision and say that any R&D done at a Federal laboratory by a company could get a more generous R&D tax credit. That would be one thing. I think the second part of this would be to make sure that any provisions or proposals that the Administration has or other proposals that try to engage universities in better efforts on technology transfer that we also apply that to Federal laboratories because there are certainly some Federal laboratories that have a lot of potential and could do a lot more.

Mr. LUJÁN. I appreciate it.

Mr. Chopra and Mr. Holland.

Hon. CHOPRA. Let me begin by saying I hope I didn't convey the impression that it was only a university focus. I think the Federal labs have a great deal to offer. In fact, I was with the Chief Technology Officer at Procter and Gamble who has created a multimillion-dollar benefit out of a collaboration with Sandia itself. So we are seeing the same principles apply. Now, there are some peculiarities in how we promote bringing of industry relevance into research activities and so there are some processes that are different, but no, we are very much committed to servicing best practices and understanding what we can do to make it work. We are doing a deep dive on the experiment that had been done in the labs to bring in entrepreneurs and residents. It may not have achieved the results we had anticipated. The venture capital community participated in that program. Trying to gather lessons learned and see how we can think anew. I was with Christina Johnson at the Department of Energy, very focused on this issue within the portfolio in collaboration with Koonan. So we are very much open and interested to finding ways in which we can collaborate on best practices with the universities and Federal labs and see that as a strong engine of new ideas for the commercial sector.

Mr. LUJÁN. And I apologize, Mr. Holland. My time has run short. Just quickly.

Mr. HOLLAND. So Representative Luján, I think it is a good news/bad news thing. The bad news aligns with the frustration that I heard in your question. The good news is, I think the venture industry is waking up to the potential in the national labs so that the NVCA does clean tech road trips where we take 40 VCs out to Sandia, Enrel, Oak Ridge and Argonne, and a number of us, including me, have actually funded projects out of the labs. On the bad news side, we were one of the participants in the EIR [Entre-

preneur in Residence] program. We took a brilliant Ph.D. physicist, we embedded him in a national lab, not in your state, for a year. He looked at a thousand projects and at the end of that time period we concluded there were none that we could put venture money behind, that we had confidence would succeed, and so I think the issue there is, it goes back to your original question. There is a fundamental disconnect, I think, between some of the activities in the work and their ability to apply those in a commercial realm, so there is sort of a bridge too far in some ways that we have to figure out.

Mr. LUJÁN. And Mr. Chairman, I know my time is up, but if you give me the flexibility to—we mentioned this to Secretary Chu as far as how can we put these incentives in to create a stronger environment, and I will give you just a quick example. There was a brain imaging scientific exploration going on at Los Alamos National Laboratories. The spin-off was that we were as a result of what happened on the failed attempt on Christmas, we were able to take that brain imaging technology and use that magnetic resonance technology to now be able to put a molecular footprint on chemicals, liquids, materials that we could identify that could be harmful in a plane. Now, there may not be an obvious technology but the spin-offs are endless, and I certainly think that as we talk about the competitiveness of the United States, Mr. Chairman, that we need to look to see how we can include our national labs in this process and see how we can get this technology off the shelf and into the market. Thank you, Mr. Chairman.

Chairman WU. Mr. Luján, always happy to give you a couple of additional minutes. You are a great representative for the country and especially those two national labs, absolutely wonderful.

I was just stunned. I was in a conversation with some of the folks at Los Alamos recently and just as an aside asked how many Ph.D.s do you have there, and the fellow said 2,700. Absolutely stunning, and we need to build a different culture perhaps and do a better job of mining what is there.

Dr. Kamlet, a couple of quick questions for you. I used to represent folks doing spinouts. Most of the time I represented the institution, and we engaged in protracted discussions about how to do the spinout, and at the risk of starving some future attorney families, you all have found an interesting way of doing business with this five percent go-in-peace policy. Have other universities adopted it? It apparently has worked well for you all. What is you evidence that it is causality rather than correlation in the step up in your spinouts, and just a couple of other questions, is it the decrease in transactions cost or an important signal to your PIs or some of each of that?

Dr. KAMLET. Well, first I should say, I mean, most of our technologies are in the IT and engineering space and it is possible that other approaches in biotech would have to take other forms, but for us it has been transformational. When I came in as Provost ten years ago, the committee that had searched for the provost had identified tech transfer as the single most broken thing at Carnegie Mellon, and it is almost impossible to overstate the ill will that occurs when you start negotiating hard with your own faculty and the transaction costs are stupendous. We have found that the sim-

ple template, five percent go in peace, has made things very transparent. It has made things very quick. It has made things very mutually friendly on both sides between us and our faculty, and we know from advisory groups that come to evaluate different parts of campus that we are now seeing by the faculty, by the researchers as this being a competitive strength for Carnegie Mellon. It is something that attracts both students and faculty to us because we have these kinds of policies, and I think other universities have not adopted this very widely but we are on their radar screen and hopefully they will in the future.

Chairman WU. Terrific. Thank you.

Mr. Holland, do you care to comment if you have had experience in negotiating with universities or research institutions and whether that has been hard or easy?

Mr. HOLLAND. I guess I would say I think it is getting better in part because of the kind of innovation we are seeing from Dr. Kamlet and others. I think that we went through a period of time where nobody really knew how to do the dance and now we have kind of figured it out. We figured out the rules that make the most sense. We have been extraordinarily fortunate in terms of rolling projects directly out of university and having them be incredibly successful, and I won't bore you with all the examples. I could give you six right off the top of the bat, and we are one of hundreds of venture firms. One that is notable is a company called Financial Engines. We funded that directly out of Nobel prize-winning work out of Stanford University. We took the professor and his top graduate student out and started this company back in 1996. Financial Engines creates these algorithms that are very interesting. They automatically help invest your retirement money. It is a lot more complicated than that but there are 58 patents associated with the work there. This is a company that took 13 years for us to get to the point where it could reach the public market. It went public two weeks ago on Monday and is now trading at about a $800 million market cap on NASDAQ so it is employing hundreds and hundreds of people, very high-quality jobs, and it was a research project directly out of a university, but as I can tell you, I can give you many, many more of those and I think, you know, quite frankly there are just some places that do it better than others. The schools that are represented on this panel do it very, very well.

We were at Carnegie Mellon two weeks ago. We commissioned some work there, a study on some things that we can't handle within our own firm on some algorithms we want to develop and so we spent a day at Carnegie Mellon, had a competition, had a bunch of students and faculty come forward with some great ideas. It was very cost-effective for us, so we love that type of collaboration.

Chairman WU. Great. Thank you very much.

Dr. Kamlet, just very quickly, this project at Olympus and the entrepreneur in residence program, I am fascinated by that. How do you set that up and how do you select the people to participate?

Dr. KAMLET. Well, the people who participate are self-selected but it is amazing how many of them respond incredibly well to a little bit of assistance. They didn't see themselves necessarily as knowing how the dance works, so to speak, in terms of commer-

cialization and we have found both students and faculty to be enormously receptive. We have tried to create what you might call an entrepreneurial ecosystem trying to provide assistance across all the points in which faculty and students interface with us, and in terms of entrepreneurs in residence, it is a process that has worked amazingly smoothly. We have to find the funding for it, but we have a very good culture for welcoming some entrepreneurs.

Chairman WU. Thank you very much, Dr. Kamlet.

I recognize the gentlelady from Maryland.

Ms. EDWARDS. Thank you, Mr. Chairman.

I want to go back to Dr. Atkinson. In your testimony you talked particularly about tax policy, and this isn't the committee to do tax policy but it is actually important to our consideration about how we structure investments in innovation, and you talked about other countries and their tax policies that have elevated them to spur investment, and one of our recommendations goes to a 30 percent credit around the idea of collaboration, which you have spoken to a great deal. I believe in investing in collaboration and I don't think you necessarily get the kind of collaboration you want unless you do invest in it. But I wonder if there is a point in time or process or research at which it is important to scale up those investments and collaboration as opposed to some other times because you could make those investments really early or allow for a 30 percent credit early but it still doesn't necessarily at the end product result in the kind of collaboration that you want to spur something toward one form of innovation into the commercial sector. So I wonder if you can give us some ideas about that or what the limitations or hazards might be in putting in and enabling that kind of credit at the outset at such a substantial amount.

Dr. ATKINSON. Sure. I guess we do see that this notion of collaborative innovation systems is critical to driving high rates of innovation that are commercialized within the United States, and we need a multitude of different policies, and we have heard a lot of them today, different policies around how intellectual property is licensed and different incentive policies and all. I do think the tax policy is one component of that. I don't think in and of itself a collaborative R&D tax credit is going to solve all the problems but I think it will help. Right now if a company wants to invest at Carnegie Mellon, and you have many, and there are at Georgia Tech as well, a lot of that research is going to be a benefit to everybody. So even though Google has a lablet there and Intel has a lablet there, the faculty aren't prohibited from publishing articles. In fact, they do publish articles. So economists would call that knowledge has spilled over and other sort of free riders, if you will, can just take it and innovate. And so there is an underinvestment of industries in university collaborative research, and to Mr. Luján's point, in Federal labs as well. So that is why we think that a tax credit could play an important role there.

One of the nice things about that too, by the way, this wouldn't involve the government picking a winner or a loser. If an industry and a university or a lab come together and they think there is something valuable in that partnership, they would be able to do that under the system. So I don't really see a lot of risks with that

other than the risk of if we only did that, I think we wouldn't do enough because you have to have a whole ecosystem.

Ms. EDWARDS. And are there standards—and maybe, Mr. Chopra, you can answer this. Are there standards or principles that could be set so that when government makes grant-type investments that you don't just encourage collaboration but you actually buy it?

Hon. CHOPRA. Well, in fact, we make those judgments within the program areas, so let me answer your question in two parts. One example is health IT as a new research and development endeavor that was called for because of the Recovery Act, and because for health IT there is a closer gap between what is done in the research environment there and what could actually be seen in the hands of the software companies who produce the goods for doctors and hospitals. Collaboration was a requirement as part of the grant request and so there was an explicit notion there that you had to collaborate not only across research institutions but also with the private sector. So that is one. And two, and this is an important point and I think the term "innovation cluster" can be described in lots of ways. From a policy standpoint, there are program mission restrictions about what they should or shouldn't fund, but what we tried to do to promote collaboration was to say if we could bring multiple agencies that have mission alignment around a particular policy objective—but come to it with their own perspectives—that we could actually achieve the kind of collaboration we are looking for without bearing all that burden on a single funded program area.

So the reference we made earlier, maybe a month ago in February, the Department of Energy initiated an energy innovation hub on building efficiency, and we are scoped to make an investment that looked like as defined in the program, but we wrapped around it the engineering research centers in the National Science Foundation. We wrapped around it Small Business Administration grant opportunities. We wrapped around it NIST opportunities to the Manufacturing Extension Program. So we stitched together seven Federal agencies who offered if an applicant could describe their approach to the innovation cluster, the collaboration that would help bring about the economic growth we would like to see out of the investment, they could apply for multiple buckets, in a sense, in a coordinated fashion. This is our first pilot of this regard.

It seems that the demand out in the field is pretty high. We had a couple of public hearings about people's interest in this. Normally you get 100 people to show up at these things. Four hundred-plus people showed up at the first of these to talk about how they could take advantage of this new initiative. As we see the results of this program, we might factor that into future activities. So some programs will have more specific language about collaboration and the solicitations themselves. Others will take this collaborative approach where they bring multiple agencies to the table to achieve the same goal. I am sure there is a better and cleaner and more efficient way of doing this but we are doing it within the constraints of the current environment, and you all will, I am sure, engage on these issues during the course of your deliberations.

Ms. EDWARDS. Thank you, Mr. Chairman.

Chairman WU. Thank you, and thank you very much, Mr. Chopra. I saw that group of 400 individuals and it was an interesting gathering, and I just want to let you know that the folks that we brought together for our little regional application for that project, the red-team analysts commented that this is the most complex offering, shall we say, that they had ever seen, and I am not sure which way to take that, but——

Hon. CHOPRA. We are learning as we go, Mr. Chairman.

Chairman WU. Mr. Luján for five minutes.

Mr. LUJÁN. Mr. Chairman, thank you very much, and I just want to say, what a useful and very valuable discussion that this has been today to get some insight and especially the level of detail that you went to in the testimony that you submitted to us as well prior to this hearing. Very insightful.

A very simple question directed to Mr. Chopra. It seems that a lot of the R&D directorates that we see with the Department of Defense and DOE are top down that we push what we want to see but there are a lot of ideas that are percolating from the bottom up. What can we do or how can we work to create an environment that can support a lot of that as well to have some flexibility with those programs as well, which is those centers were originally created for but other programs that do exist for some of these collaborations to allow for that to happen?

Hon. CHOPRA. Well, thank you very much. That happens to be an area that I have a great deal of passion for, which is balancing the top down from the bottom up, and here I would like to invoke the President's open government initiative where we are trying to change the way Washington works by being much more transparent and collaborative and participatory so we can find great ideas from the bottom up and see that they have a chance to take hold, and this applies beyond R&D. This is a philosophy we are taking to every Federal agency. I will mark the date April 7th when each of the Federal agencies, the Cabinet agencies in particular, will be publishing open government plans as directed by the directive that had been issued back in December. You will see a great deal of strategy in each of those plans outlining how agencies will service bottom up new ideas that can be implemented. Specifically, I will point to a line in that directive referencing prizes, competitions and challenges.

When the President issued the open government directive, one of the key deliverables coming out of it was produced on March 8th, guidance from OMB [Office of Management and Budget] to all Federal agencies on how we can thoughtfully utilize prizes, competitions and challenges to do the kind of thing you are describing, bring ideas up that hadn't been conceived and detailed requirements that go over 500 pages of material where you know exactly what you are looking for. That is a culture change in Washington. I am not going to suggest it is going to happen immediately but we are starting to see the fruits of that activity. More and more of our agencies are thinking about ways that they can capture both frontline worker innovations, perhaps the Federal labs might be another example, as well as innovations out in the private sector.

I will give you just one agency in particular, the Veterans Administration. They have been trying to get the claims backlog down

forever, and as many of us know, it is a top priority for nearly every presidency is to serve our veterans at the highest standards yet the claims backlog continues. President Obama in August said "I want the 19,000 frontline workers to give us your best ideas." We ran a business plan competition, picked the 10 best. Those are being implemented as we speak, but a gentleman from Togus, Maine had a simple idea that didn't cost us a nickel to restructure our performance measures so that we could create a culture of accountability for results. He wouldn't know that his idea would go anywhere. Togus, Maine put it in their business plan, came down to Washington, made the pitch. Secretary Shinseki said yes, this is it. They are now executing, and by July that will be implemented at zero additional cost. So we are going to do this, I hope, in every one of our agencies.

Mr. LUJÁN. I appreciate that.

And Mr. Holland, and this goes for the entire panel, I am very interested in getting whatever analysis was conducted with that pilot project that you engaged with, with working with the national laboratories to see what failed, and for that matter, hearing from any companies that you have worked with or that are out there that have positive stories and negative stories so that we can see what we can do to learn from that and see how we can integrate that to make a much more friendly environment to allow for this to move forward.

Mr. HOLLAND. Given the nature of the time constraints, we have other more positive stories to share and I am happy to take those offline with you. One is around some of the work at Oak Ridge around their energy efficiency smart homes, and our clean tech practice at the foundation happens to specialize in energy efficiency, smart grids, smart materials. So one of our companies has their windows installed in this smart home. The windows are actually manufactured in Pittsburgh, just outside of Pittsburgh. But we have got great stories around that type of thing. But the bottoms-up nature of what you are talking about is a huge issue for us. It is what we call deal flow, and it is actually probably the most important thing in our industry.

One of the things that we are working on now, and you all, thank you for so many things about this meeting but one is, you saved me a couple plane flights because we are going to be hitting up our friends at Carnegie Mellon and Georgia Tech to participate in a program that we are going to start, having us basically hire students to be campus reps, and we want those campus reps to be the equivalent of kind of little miniature AWACS [Airborne Warning and Control System] planes. We want them sort of buzzing around the area and notifying us when they see something that looks interesting, looks like it could be a good project. A project can come from anywhere. It could come from the university, come from the local area. We are looking very closely at a company in Pittsburgh called Mod Cloth right now that was funded out of two students that happened to be married who were undergraduates at Carnegie Mellon. That is the kind of stuff that we live and breathe for, so we are very interested in this whole notion of bottom up and we are spending a lot of time on it.

Mr. LUJÁN. Thank you.

Thank you, Mr. Chairman.

Chairman WU. Thank you very much.

Mr. Holland, we read your materials about facilitating collaboration and we acted on it promptly.

Three very, very quick questions. I hope to get this in in my last five minutes. Dr. Kamlet, you suggest, and I think a couple other people also suggested, that there are some funding issues. The Technology Innovation Program and SBIR don't cover the spectrum of taking a product from the lab to commercialization and that we need to address earlier as well as later funding, if we could quickly tap on that and then move on.

Dr. KAMLET. Yes. The government's main role of course is in the domain of basic research but it is also the case that before Mr. Holland and his organizations can take a product, it has to reach a certain potential in terms of commercial capability and have progressed to the point in which there is a clear functionality and intellectual property and so forth, and it is really before something is ready for an SBIR or for venture funding because that requires a company to already have been formed. That chasm exists, and in order to get the most mileage from the basic research to translate into commercialization, spending some attention on trying to find funding mechanisms to take not large amounts, $50,000, $100,000. There should be a lot of accountability attached to it but that is a current gap in which unless we find funding from foundations or conceivably do it ourselves, there is no basis in the ecosystem and the American structure and the universities to fund those kinds of things.

Chairman WU. Well, shoot, you know, maybe the feds can just match what Carnegie Mellon is willing to put on the table in terms of indirect cost recovery funds.

Dr. KAMLET. Well, we can talk.

Chairman WU. If no one else wants to comment on that, Dr. Atkinson, you and Dr. Breznitz mentioned that some of our innovation is perhaps better done at the state level or that coordination is better done at the state level, and I wanted you to address that a little bit further because quite frankly, that is something that I have not focused on despite all the activity that has been going on in my neck of the woods with Onami and others.

Dr. ATKINSON. Sure. Within the last perhaps 15 years, I think one of the biggest changes in the U.S. innovation system is that virtually every state has developed some programs and policies to spur technology-based economic development, and it is completely divorced from party lines so Republican governors do this just as actively as Democratic governors. The big problem with that, though, is that the incentive for them is limited because sometimes it takes innovation policies five to ten years to pay off. I don't think a lot of governors are thinking five to ten years down the line. Oftentimes they have to worry about their reelection. And secondly, a lot of these policies sometimes will spill over into other states. So our view is that the United States is so big—Dr. Breznitz mentioned Finland, great, interesting programs there. They are sort of like a state. The United States is so big that we can't really have a national innovation system that is completely run from Washington. The people who are running the technology group in Pitts-

burgh that the state helps fund, they know about these projects in Pittsburgh pretty well but I don't think Washington knows about them. Same thing in Portland. That is why Oregon has a program like that. So the problem though, is that these programs are underfunded, and if the Federal Government could support them in a more systemic way and tie them also to the development of long-term strategies around innovation, as you, Dr. Breznitz, have alluded to in your testimony, I think that would really go a long way. I think we have an undervalued resource here as partners with the states and it is, I think, time for a Federal-state innovation partnership.

Dr. BREZNITZ. Thank you for this question since, as you know, I am very much interested in this. I can give an example from Georgia, so for example, we conducted a study at Georgia Tech about what happens to a cluster of high-tech industries in Atlanta and we found out it is stagnant, so it grew and then it is stagnant for about ten years, and we tried to figure out what it is. Money? No. Good people? No. We found out it is basically a secret sauce of Silicon Valley, collaboration. Companies do not collaborate. And in order to make the Atlanta cluster better, therefore you had to have a program that understands how to connect the actors within the Atlanta region. This is something that the Federal Government can't even know and therefore we need to go to the state levels if we talked about bottom-up ideas and understand what some of the limits, constraints, ideas that they have and we can probably do that as the Honorable Chopra said by giving competitions. If you want to have a really innovative idea to look for your region and your city, you have to submit a proposal for a competition and the Federal Government can give you a certain amount of money or tax credits and make it happen. An experiment that works can be replicated and the Federal Government can make sure that if you want to do semiconductors, which is all around the Nation, and have three or four of those competitions, you can coordinate with them and that way we can bring the forces and the knowledge from the bottom up and from the Federal Government and have a national strategy at the same time.

Chairman WU. Terrific. Thank you. My understanding is that there are no more questions form the panel except for this last one from me. Lessons from DARPA, ARPA–E and NASA. Many people have talked about the good model that DARPA has provided. DARPA and NASA were started at about the same time, and we might have some lessons about how each has or has not spurred private sector innovation, and finally, our experience to date with ARPA–E. I don't know if we have had enough run time to draw any conclusions but if the panel would like to comment on at least these three organizations and their effect on innovation in America.

Hon. CHOPRA. You know, I would not want to speak for the directors of the programs that you have referenced to describe their success, but I will tell you from my vantage point, a key to their success is understanding a problem that they wanted to solve. When you have a problem, an itch you are trying to scratch, a problem you are trying to solve, you can be much more effective in bringing together an ecosystem to help you address the particular problem that you are looking to solve. That is, in a sense, that equation of

ideas and relevance equals innovation. So I think a key in DARPA in particular and NASA as well, it is really early in ARPA–E but it is part of the DNA there, is a really thoughtful understanding of the problem. That allows there to be a creative approach to tackling that problem and that I think has been much more effective to produce relevant ideas that hopefully have the ability to translate in the commercial sector.

Dr. ATKINSON. I will just make one comment, there was a report that we had an event on with a Carnegie Mellon professor, Erica Fuchs, who is an engineering and also public policy professor, and she has done a very in-depth study of DARPA over the long history of DARPA and when it was more successful and less successful at spurring innovation sort of beyond just the Defense Department. And what she found was that DARPA was most successful when it didn't just focus on their narrow mission and it had a more broader and expansive role, also going to Mr. Chopra's point about still had focus but it wasn't just we are trying to do this very narrow thing. So I think that is important for an agency like DARPA or ARPA–E to maintain that somewhat broader focus on spurring innovation, and DARPA has been able to do that sometimes quite successfully and other times less successfully.

The last point I will make is, one of the things that I do think, though, it is important to recognize that there are innovation challenges in the United States that aren't related only to mission needs, and I think that is a big gap that we have and other countries—talk about a leader is Taiwan. I mean, they really are focused on some technologies that are driving their economy and have been quite successful but aren't really related to national government mission needs.

Dr. BREZNITZ. On that point, two remarks. I think DARPA—and I know Erica very well. We have been officemates at MIT when we were both slightly less young. DARPA was very, very successful when it managed to become a facilitator for private actors and universities to work together and come up with great ideas and fund them to do research that otherwise would not have been funded. When it saw its main role in creating those networks, making them happen and letting them run, it was amazingly successful. And the same goes for Taiwan. When Taiwan was amazingly successful as a research foundation, very similar to a national lab, in creating the private industry—the most famous one is semiconductors—is when it understood what its main role and its main metrics and benchmarks would be the creation of new companies that brings on billions and come up from new ideas and new collaboration with itself, universities and private entrepreneurs, and I think that is part of a facilitating role of the Federal Government that I would like to see more of.

Chairman WU. Terrific. Thank you all very much. This has been such an important discussion. I just wish that it had the draw of, say, doing a hearing on steroids in baseball. But putting the economy on steroids just doesn't have the same draw.

I very much share with you all the view that America's best days are ahead. The balance with that sort of quintessentially American optimism about the future, I think it also behooves us to look over our shoulder. A few years ago when I was visiting China, and I vis-

ited a number of research institution and universities, but I also took the time to visit a high school, and we had a vigorous discussion there. It was absolutely terrific. It was very similar to the discussions that I have with high school students at home in Oregon. But the question that came up that I want to recall now is this Chinese high school student asked me what do you think is America's greatest strength, and I thought about it for a second and I said well, actually paranoia, paranoia about whether we are staying ahead, whether someone is catching up, and I think that sometimes we can overplay that concern and that can infect our optimism in negative ways and we should not have either a blind optimism or blind paranoia, and striking that balance is a very important role for anyone who leads the public, and I think that we all have an important role to play in that.

Again, I want to thank you all for appearing before this Subcommittee. I view this as part of a continuing dialog and look forward to looking for both legislative opportunities and convening opportunities and other opportunities to push our agenda forward in stimulating innovation in America.

The record will remain open for two weeks for additional statements from the Members and for questions to the witnesses.

The witnesses are excused. Thank you very much. The hearing is now adjourned.

[Whereupon, at 12:24 p.m., the Subcommittee was adjourned.]