Rising to the Challenge: U.S. Innovation Policy for Global Economy

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Charles W. Wessner and Alan Wm. Wolff, Editors; Committee on Comparative National Innovation Policies: Best Practice for the 21st Century; Board on Science, Technology, and Economic Policy; Policy and Global Affairs; National Research Council

Overview

America's position as the source of much of the world's global innovation has been the foundation of its economic vitality and military power in the post-War era. No longer is U.S. pre-eminence assured as a place to turn laboratory discoveries into new commercial products, companies, industries, and high-paying jobs. As the pillars of the U.S. innovation system erode through wavering financial and policy support, the rest of the world is racing to improve its capacity to generate new technologies and products, attract and grow existing industries, and build positions in the high technology industries of tomorrow.

Sustaining global leadership in the commercialization of innovation is vital to America's security, its role as a world power, and the welfare of its people. Even in a climate of severe budgetary constraint, the United States cannot afford to neglect investing in its future. These are investments, moreover, that will pay for themselves many times over.

The second decade of the 21st century is witnessing the rise of a global competition that is based on innovative advantage. To this end, both advanced as well as emerging nations are developing and pursuing policies and programs that are in many cases less constrained by ideological limitations on the role of government and the concept of free market economics. Not only have these nations placed massive bets on research and higher education, they have also unveiled comprehensive national strategies to build innovation-led economies. Governments everywhere are adopting, adapting, and in some cases improving aspects of America's innovation ecosystem that have long been the envy of the world, such as close collaboration between universities and business, deep pools of risk capital, and effective programs that encourage researchers to start up their own companies. Going beyond, some countries are pursuing a highly interventionist and essentially mercantilist set of innovation policies and programs.

The rapid transformation of the global innovation landscape presents tremendous challenges as well as important opportunities for the United States. Emerging powers such as China and India have critical masses of highly educated scientists and engineers, rising R&D spending, and large, rapidly growing domestic markets for high-tech products. Innovation hubs such as

Silicon Valley, greater Boston, San Diego and Austin that have been magnets for the world's brightest and most visionary innovators, technology entrepreneurs, and investors face greater competition from dynamic new commercialization zones, such as Taipei, Shanghai, Helsinki, Tel Aviv, and Bangalore.

The world of innovation itself is undergoing radical change, calling into question America's ability to benefit fully from U.S. science and technology leadership. In today's world, knowledge, money, and people flow across borders with ever-greater speed and ease, often through open collaborative innovation networks linking corporations, researchers, investors and institutions. The good news is that this opens genuine opportunities for international collaboration that can help solve global health, environment, and energy challenges, as well as enable companies to accelerate product development.

But the globalization of innovation capacity is also undermining traditional assumptions that have guided U.S. policymaking for the past six decades. In particular, it no longer follows that discoveries and inventions flowing from research conducted by America's universities, corporations and national laboratories will naturally lead to products that are commercialized and industrialized on U.S. shores. Although the U.S. federal government remains the biggest sponsor of basic research, spending some $148 billion on public R&D in 2011, traditional trading partners and emerging economies are concentrating their energies on translating new technologies from every available source into industrial applications and job-generating industries. In some cases, nations are using the resources of the state to induce U.S. companies to manufacture their innovations locally and transfer proprietary technologies while giving homegrown champions privileged access to their domestic markets. In other cases, companies produce offshore because they conclude the United States simply lacks the supply chain capacity, technical skills, and the right investment climate for high-volume manufacturing. As a result, the U.S. is finding it increasingly difficult to capture the economic value generated by its tremendous public and private investments in R&D.

The United States urgently needs to adjust to the new great game [or challenge] of 21st century global competition. Just as the 2007 National Academies report *Rising Above the Gathering Storm* was a call to arms that urged the U.S. to increase investment in R&D, education, and other inputs into the innovation system, this report argues that far more vigorous attention be paid to capturing the outputs of innovation -- the commercial products, the industries, and particularly high-quality jobs to restore full employment. America's economic and national security future depends on our succeeding in this endeavor.

THE NEW INNOVATION LANDSCAPE

The search for a new U.S. innovation policy should begin with an understanding of America's changing competitive position as compared with the rest of the world. Over the past several years, the Board on Science, Technology, and Economic Policy of the National Academies has engaged in an extensive dialogue on science, technology and innovation policy with countries that place a high priority on innovation. America's competitive challenge comes into clearer focus when the strong measures taken by other nations to improve their innovation capacity are contrasted directly with the flagging U.S. commitment in many of the same areas. For example:

Support for the Pillars of Innovation:

- **R&D Investment:** The U.S. is losing its once-overwhelming advantage in research. The U.S. share of global R&D spending dropped from 39 percent in 1999 to 34.4 percent in 2010. This is still very substantial, but trends suggest the U.S. share will continue to shrink. While American R&D spending has risen 3.2 percent a year on average for the past decade, for example, growth in South Korea has averaged 8 percent annually and China has averaged 20 percent. Brazil nearly tripled R&D spending between 2000 and 2008, and Singapore plans to triple spending between 2010 and 2015. U.S. federal spending on basic research as a percentage of GDP, which is critical to future technological progress, has virtually stagnated for the past 20 years and risks actual decline in the face of current fiscal pressures.
- **University Funding**: Research universities—the engines of the U.S. innovation system—are suffering severe cutbacks across the U.S. due to state budgetary constraints. Other nations and regions are dramatically increasing funding to upgrade, expand, and open new research universities. China is spending billions to make 39 universities world leaders. India's five-year plan calls for 1,500 new universities and a number of new elite technology institutes. And Taiwan plans to invest $1.7 billion to develop world-class universities.
- **Early-Stage Finance:** Funding from angel investors and venture capitalists, another pillar of America's innovation ecosystem, has fallen sharply since 2000 (albeit a peak year), and venture capital investors have grown steadily more risk-averse, putting less funding in the early-stage investments. But successful U.S. programs, such as the Small Business Innovation Research (SBIR) program, that are important sources of early-stage funding have struggled for reauthorizations. Others, such as NIST's Advanced Technology Program, now the Technology Innovation Program (TIP), have struggled for renewed funding. Meanwhile, other nations have launched large funds to support

start-ups. Japan, Brazil, the United Kingdom, Sweden, India, the Netherlands, Germany, and other nations have adopted programs that often are modeled directly on SBIR or other U.S. policies and address the early-stage funding challenge in the innovation chain.

- **Talent**: Singapore, Canada, and China are among the nations that are attracting star scientists from around the world to their universities and research institutes by offering high salaries and opportunities to run well-funded programs. In the U.S., foreign-born U.S. science and technology graduates and entrepreneurs often face great difficulty obtaining U.S. residency visas and citizenship. Others are investing more in their existing workforce. Germany, for example, is a pathfinder in high-skilled worker training and retention, including dealing with the both the challenge and opportunities presented by an aging population. By contrast, the U.S. lacks any systematic worker-retraining program in an age of drastic technological change.

Efforts to Capture Economic Value:

- **Manufacturing.** U.S. is losing competitiveness as a location for new investment in advanced manufacturing capacity, even in industries where the U.S. is at the technological forefront, driven in part by national policies. This continued erosion of America's high-tech manufacturing base threatens to undermine U.S. leadership in next-generation technologies. Major U.S. trading partners understand that a domestic industrial base that can produce advanced products in high volumes is integral to maintaining global competitiveness in innovation and next-generation technologies. Nations and regions as diverse as Germany, Japan, Taiwan, and South Korea are showing it is possible to remain successful exporters in advanced manufacturing despite relatively high labor costs. The U.S. high-tech manufacturing base, by contrast, has deteriorated to the point that it is sometimes difficult to manufacture in high volumes the products that are invented in the United States —even when labor costs are not a major factor. While many other nations support high-volume manufacturing with tax holidays, grants and credit, U.S. federal incentive programs have short time horizons, limited scope, and uncertain future funding prospects.
- **Translational and Applied Research**: In a time of intense technological change, large, well-funded public-private partnerships such as Germany's Fraunhofer-Gesellschaft, Korea's Electronics and Telecommunications Research Institute, Taiwan's ITRI, and Finland's Tekes have proven remarkably successful at helping domestic manufacturers translate new technologies into products and production processes. Although the U.S. has many applied-research programs, we lack a systematic institutional focus on developing manufacturing

industries at scale for new technology products and or to reinforcing and stimulating the growth of broad industrial clusters.

- **Cluster Development**: Governments around the world are investing aggressively in comprehensive strategies to foster regional innovation clusters. Prominent government-supported successes include the semiconductor, digital display, and notebook PC clusters in Taiwan; telecommunications in Finland; biomedical research in Singapore; micro-electronics in Grenoble, France; and life sciences and information technology in Shanghai's Pudong district. Many promising innovation-cluster initiatives have been launched by U.S. state and local governments, including nano-electronics in upstate New York, advanced batteries in Michigan, flexible electronics in northern Ohio, and biometrics in West Virginia. Unlike in other nations, however, many of these initiatives receive little federal policy or financial support—and new federal initiatives are often small.

Efforts to Enhance National Advantage:

- **Framework Conditions**: The United States still offers one of the world's best environments for commercializing products and launching companies, including strong protection of intellectual property rights, temperate bankruptcy laws, well-developed capital markets, and extensive worker mobility. But the U.S. has not stayed abreast of other nations in areas as diverse as tax policy, regulatory costs, and state-of-the-art infrastructure.
- **Rising Neo-Mercantilism:** Countries such as China and South Korea employ a powerful combination of state subsidies, national standards, preferential government procurement for national firms, and requirements for technology transfer to drive the growth of nationally-based innovation. They also encourage state- owned or –supported enterprises to compete globally in strategic emerging industries with the help of low-cost loans—often with little concern for near-term return on investment or overcapacity. In the United States, trade and investment policy is predicated on the faith that open markets foster innovation. What's more, U.S. trade policy is ill-equipped to avert the serious damage neo-mercantilism inflicts on U.S. industries until it is too late, such as when heavily subsidized competition of a given product forces American manufacturers to shut domestic production. Often, U.S. companies hesitate to seek redress from the federal government because they fear damaging their access to foreign markets. By depriving U.S. companies of the ability to reap the commercial rewards of their significant investments in innovation both at home and abroad, neo-mercantilism poses serious long-term consequences for the U.S. economy and defense capabilities.

RISING TO THE CHALLENGE

In this dramatically more competitive world, the United States cannot return to a path of sustainably strong growth, much less maintain global leadership, by living off past investments in its capacity for innovation. By failing to make the immediate as well as long-term investments needed to ensure that the U.S. remains a dominant location for producing technology-intensive goods and services, we are sacrificing jobs, economic growth, living standards, and national security. Nor can the U.S. compete on the basis of a policy approach that is the legacy of an era when American advantages were overwhelming and innovative activity tended to remain within our borders.

Since publication of *The Gathering Storm*, Congress and the White House have taken a number of measures to shore up U.S. competitiveness in science, technology, and economic policy, though many have lacked adequate follow-through. The reauthorization of the America COMPETES Act, signed into law Jan. 6, 2011, called for sharp increases in the research budgets of federal agencies and federal funding for K-12 science, technology, and mathematics education. However, Congress has not followed up this call with funding and the Obama Administration has proposed flat science budgets below the levels proposed in the legislation. The original America Competes Act also established the Advanced Research Projects Agency-Energy (ARPA-E), which received funding only following the passage of the American Renewal and Reinvestment Act of 2009. In addition to funding ARPA-E, this Stimulus Bill eased immigration rules for skilled talent, and extended billions of dollars in grants and loans to renewable-energy, electricity-transmission, and advanced-battery manufacturing projects, but this was a one-time event. The Obama Administration has unveiled a national innovation strategy that calls for increasing U.S. investments in R&D, higher education, and information-technology and transportation infrastructure along with many other more-targeted innovation programs, such as the National Manufacturing Initiative.

As encouraging as these actions are, they are not enough. Many of the major proposals aimed at boosting U.S. competitiveness and reaping more of the economic value from U.S. innovation have not been enacted into law. Most of the new pro-innovation programs have short time horizons and may well lack sustainable long-term funding. Federal programs also lack the scale and comprehensive approach needed to enable America to rise to meet the acute competitive challenges posed by the rapidly evolving global innovation landscape. We therefore recommend the following strategy to start putting the United States on a clear path to meeting these challenges:

In a dramatically more competitive world, the United States needs to reinforce the traditional pillars of its economic strength and innovation capacity. (Recommendation 2.)

- **Boost R&D investment**: The U.S. should fund R&D at the higher levels authorized under the America COMPETES Act and sustain these levels in the future as part of a plan to boost private and public R&D expenditure to a level of 3% of GDP by 2020. (Recommendation 2a.)
- **Sustain University Research**: Funding for university research should be stabilized at the state and federal level and then increased. Our capacity to train students in science, engineering and mathematics, and in the broad range of future demands for talent, is dependent on well-funded universities and colleges. Funding options should include targeted business tax incentives from dedicated sources of tax revenue as well as incentives for private donations. The government also should reform regulations that make it increasingly expensive for universities to conduct research. (Recommendation 2b.)
- **Help Small Business:** Innovative small businesses are a major source of new job creation. However, many small firms and struggle to raise the funds needed to develop promising new technologies because their commercial potential is often too uncertain to attract needed private venture capital. Proven programs such as SBIR and ATP (or its successor, the Technology Innovation Program), which provide small competitively based innovation awards to small firms or consortia, should be sustained, expanded, and adequately funded. Government agencies should also be encouraged to experiment with and evaluate new initiatives, including prizes for technological advance. The U.S. government should explore offering policy support for angel funds and venture capital. (Recommendation 2c.)
- **Train Workers:** The federal government should expand support for successful state and regional workforce-development programs for advanced industries. It also could provide companies with vouchers to cover training costs for new employees. Programs in community colleges that provide such training need to be reinforced. To encourage experienced talent to remain in the workforce longer, the U.S. should remove tax disincentives for staying employed past age 65. (Recommendation 2d.)
- **Support higher education.** Federal and State governments should make sure that education in all fields, and particularly science, technology, engineering and math, are made affordable and available to all eligible applicants. The land grant colleges were the backbone of the talent infrastructure for the building of America, and the Federal role should not be abandoned now. (Recommendation 2b-i.)
- **Attract Foreign Talent:** Immigration laws should be reformed to attract foreign scientists, engineers, and entrepreneurs to live and work in the U.S. and facilitate their permanent residency and U.S. citizenship. (Recommendation 2d-v)

The United States needs to adopt specific policy measures to capture greater economic value from its public investments in research. (Recommendation 5.)

The America COMPETES Act provides for crucial inputs into the U.S. innovation system. But a similarly comprehensive effort needs to be made to exploit the results of these investments in science, technology, and education into more innovative products and well-paying jobs.

- **Support Advanced Manufacturing:** A 2004 report of the President's Council of Advisors on Science and Technology warned that "with manufacturing leaving the country, the United States runs the risk of losing the strength of its innovation infrastructure of design, research and development and the creation of new products and industries." Many U.S. companies with important technologies cannot develop the full infrastructure and make the high-risk, long-term investments required to support job-creating advanced manufacturing at home. To help stem this erosion of the nation's manufacturing base, current manufacturing tax credits and loan-guarantee programs should be made permanent and expanded in scope. Manufacturing technical assistance and other programs aimed at accelerating commercialization of new technologies should be expanded. In particular, the recent proposal to set up a network of Manufacturing Innovation Institutes should be fully funded. (Recommendation 5d.)
- **Leverage government procurement:** Federal agencies can use their purchasing power to help drive domestic commercialization of emerging technologies. The U.S. government has done this many times previously in industries such as semiconductors, computers, and aerospace. Federal and state agencies can help build domestic markets for important new technologies for electric-drive vehicles, energy-efficient buildings, solid-state lighting, and next-generation photovoltaic cells. Procurement rules of Federal agencies and armed forces should be reformed to put more emphasis on providing incentives for spurring innovation in products and processes that result in continuous performance improvements and lower long-term life-cycle costs (vs. up-front costs). Government agencies also should accelerate innovation by providing early-stage financial support for small companies that can address national needs. (Recommendation 5j.)
- **Foster Clusters:** Recent pilot programs by federal agencies to align current economic development programs with specific regional innovation cluster initiatives by state and local organizations should be assessed and, where appropriate, expanded geographically. The U.S. also needs to assess and draw policy lessons from successful cluster efforts and communicate best practices to those managing regional initiatives.

The Federal government should award competitive grants to support state and regional efforts to develop and sustain modern science parks and also technology development implementation centers that are focused on manufacturing. (Recommendation 5i)

- **Strengthen University Links to the Market:** University seed funds and incubators can help start-ups spun off from research projects. Early-stage funding programs should be expanded to support commercialization of university research. New centers of excellence should be established to foster university-industry-government collaboration on commercial and industrial applications of emerging technologies. (Recommendation 5a.)
- **Promote Public-Private Partnerships:** The U.S. needs to expand successful partnership programs and consider adopting and adapting successful models from abroad, such as Taiwan's ITRI and Germany's Fraunhofer Institutes. The U.S. also should assist in establishing new public-private research and development consortia aimed at fostering the implementation and production in the U.S. of emerging technologies in sectors such as flexible electronics, solid-state lighting, and medical devices. (Recommendation 5c.)

Provide a Competitive Corporate Environment: The United States should assure that the tax framework supports new company creation and investment. In order to be competitive with those of its major trading partners, the U.S. should take measures to address policies that actually disadvantage U.S.-based industry. (Recommendation 3)

Governments at the Federal and state levels should regularly benchmark tax policies and regulatory costs against those of other nations. Where they are found to be serious impediments to corporate investment and innovation, every effort should be made to close gaps or seek ways to reduce the negative impact through compensating incentives. The U.S. should consider reducing corporate taxes and rely increasingly on consumption taxes. Efforts should be made to ensure that changes in taxation and government spending to shrink the federal deficit are made with a full understanding of the potential consequences for future growth. The U.S. should also make current tax credits for research and experimentation permanent, and incentivize commercial credit to innovative manufacturing, particularly the scale-up of an initial production process.

Build a 21st Century Innovation Infrastructure: The U.S. should increase dramatically investment in state-of-the-art broadband networks and other infrastructure required to maintain American leadership in a 21st century global knowledge economy. (Recommendation 4.)

The U.S. should consider the feasibility of a National Infrastructure Bank that can leverage more private investment in highways and railways, renewable-

energy systems, water and sewerage and other public works that both meet critical national needs and deploy emerging technologies. The Federal government should increase R&D investments in new materials and sensors for highways, ports, and bridges, as well as technologies to improve energy efficiency in buildings. Incentives to encourage expansion of the high-speed Internet backbone should be strengthened to sharply increase broadband penetration in homes, schools, and businesses.

Capitalize on Globalization of Innovation: The United States should capitalize on the globalization of research and innovation to cooperate with other nations to advance innovations that address shared global challenges in energy, environment, health, and security.(Recommendation 7.)

Just as other nations establish R&D institutions in the U.S. and actively seek to acquire American technology, the United States should recognize the many opportunities presented by the rapid growth in research and innovation activity abroad.

- **Research Collaboration**: The U.S. needs to strengthen and expand research collaborations with growing economies such as China, India, and Brazil; new European Union members such as Poland, the Czech Republic, and Hungary; and historical partners like Sweden, Germany, and Japan to advance research that can lead to innovations in biomedicine, energy, environment, security, and other shared global challenges. To stay abreast of important technological developments abroad, the United States should expand exchanges of researchers, scholars, and students, and support these objectives. (Recommendation 7a.)
- **Network and Engage Globally.** We now operate in global systems of innovation and new knowledge creation. Leading scientists at American universities work in collaborative teams and cohorts that are multinational and dispersed across the globe joined together by strong information technology networks. We need to better leverage these networks and capture value from them. (Recommendation 7b.)

Monitor and Evaluate Investments, Measures, and Innovation Policies of other Nations: In a world where other nations are investing very substantial resources to create, attract and retain the industries of today and tomorrow, the United States needs to increase its understanding of the swiftly evolving global innovation environment and learn from the policy successes and failures of other nations (Recommendation 1.)

The United States needs to understand the swiftly evolving global innovation environment and the implications for America's competitive

position and national security. The government should, as a priority, gather current information and assess current implications for the U.S. economy of foreign programs, and at the same time maintain and support regular, on-going efforts to engage with policymakers, business leaders, and academics from around the world. These steps will enable the benchmarking of U.S. policies, programs and measures in light of those of other countries. The U.S. needs to be able to draw upon international best practices aimed at advancing innovation in order to inform its own policies and programs and understand the potential impact of these programs on U.S. industries.

Recognize that Trade and Innovation are Closely Linked: (Recommendation 6.) It is the responsibility of the U.S. government to provide a rules-based global playing field for its industries. Foreign trade- and investment-distorting measures should be rooted out or offset, especially when U.S. innovation will be stifled. This will require support

Box O-1
Four Core Goals

1. **Monitor and learn from what the rest of the world is doing:** The United States needs to increase its understanding of the swiftly evolving global innovation environment and learn from the policy successes and failures of other nations. It is generally recognized that there is much to be learned from the rest of the world in science. This is equally true with regard to innovation policy. See Recommendation 1.
2. **Reinforce U.S. innovation leadership:** It is very important that the United States reinforce the policies, programs, and institutions that provide the foundations for our own knowledge-based growth and high value employment. These include measures to strengthen our research universities and national laboratories, renew our infrastructure, and revive our manufacturing base. See Recommendations 2, 3, and 4.
3. **Capture greater value from its public investments in research:** The United States should improve its ability to capture greater value from its public investments in research. This includes reinforcing cooperative efforts between the private and public sectors that can be grouped under the rubric of public-private partnerships, as well as expanding support for manufacturing. See Recommendations 5 and 6.
4. **Cooperate more actively with other nations:** In an era of rapid growth in new knowledge that is being generated around the world, the United States should cooperate more actively with other nations to advance innovations that address shared global challenges in energy, health, the environment, and security. See Recommendation 7.

from U.S. industry, but ultimately be founded on an independent and well-informed judgment on the part of the U.S. government as to the policy responses that are in the national interest. The United States government should begin to focus attention on the composition of its economy and the extent to which it is being shaped by foreign industrial and trade policies.

Based on intelligence gathered as recommended in this report, and without waiting for the filing by private parties of trade cases, the U.S. government should determine whether the national interest requires that solutions need to be put into place. It needs to vigorously pursue changes in policies of other governments that are harmful to the U.S. industrial base and innovation process and, where policies cannot be changed, offset them with trade measures or financial support for affected domestic industries as necessary.

In addition, every new U.S. international trade or investment agreement should include a comprehensive code of conduct governing the commercial activities of state-owned enterprises, holding their governments accountable for behavior that undermines fair competition and deprives other nations of the economic benefits of their investments in innovation.

CONCLUSION

The U.S. innovation system still enjoys many advantages: the world's largest research infrastructure, a number of the world's greatest universities, the deepest capital markets, and a highly dynamic ecosystem for knowing how to turn inventions into products and businesses. But in a world where other countries are rapidly developing their own innovation capacities, these advantages alone will not guarantee America's future competitive advantage.

Other governments are assertively shaping policies and programs to change the competitive landscape in their favor. U.S. policies and programs are based on a historical position of national leadership and endowment following World War II that has long since been replaced by a broad equilibration of technical and economic capabilities and fundamental changes in the ways in which technologies are developed and implemented. The U.S., while retaining vestiges of its leadership position, should recognize that merely maintaining the current policies and programs will lead to continued erosion of our economic capabilities, especially in high technology industries that are the basis for future prosperity.

The U.S. has every opportunity to secure its economic leadership and national security well into the future. But it will require a fresh policy approach, one that ensures that the United States can compete, cooperate, and prosper in this new world of competitive innovation. The recommendations of this report

strongly urge a reformulation of U.S. innovation policies to address this changing competitive environment.

PART I

THE INNOVATION CHALLENGE

RISING TO THE CHALLENGE

U.S. Innovation Policy for the Global Economy

Committee on
Comparative National Innovation Policies:
Best Practice for the 21st Century

Board on Science, Technology, and Economic Policy

Policy and Global Affairs

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Project Staff

Charles W. Wessner
Study Director

McAlister T. Clabaugh
Program Officer

David S. Dawson
Senior Program Assistant

David E. Dierksheide
Program Officer

Sujai J. Shivakumar
Senior Program Officer

Peter J. Engardio
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Consultant

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of Engineering and Information
Technology
Special Advisor to the Chancellor
for Economic Development
University of Arkansas
at Little Rock

William H. Janeway
Partner
Warburg Pincus, LLC

Richard K. Lester
Japan Steel Industry Professor
Head, Nuclear Science
and Engineering
Founding Director, Industrial
Performance Center
Massachusetts Institute
of Technology

continued

*As of June 2012.

William F. Meehan III
Lecturer in Strategic Management
Raccoon Partners Lecturer
in Management
Graduate School of Business
Stanford University
and
Director Emeritus
McKinsey and Co., Inc.

David T. Morgenthaler
Founding Partner
Morgenthaler Ventures

Arati Prabhakar
Atherton, CA

Luis M. Proenza
President
The University of Akron

William J. Raduchel
Chairman
Opera Software ASA

Kathryn L. Shaw
Ernest C. Arbuckle Professor
of Economics
Graduate School of Business
Stanford University

Laura D'Andrea Tyson
S.K. and Angela Chan Professor
of Global Management
Haas School of Business
University of California, Berkeley

Harold R. Varian
Chief Economist
Google, Inc.

Alan Wm. Wolff
Senior Counsel
McKenna Long & Aldridge LLP

STEP Staff

Stephen A. Merrill
Executive Director

Charles W. Wessner
Program Director

Paul T. Beaton
Program Officer

David S. Dawson
Senior Program Assistant

McAlister T. Clabaugh
Program Officer

David E. Dierksheide
Program Officer

Aqila A. Coulthurst
Program Coordinator

Sujai J. Shivakumar
Senior Program Officer

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Preface

The ability to combine theory, creativity and engineering was a great achievement of postwar America. For 50 years, economic growth and job creation were propelled by transistors, lasers and other discoveries that came from the willingness to nurture theoretical research in conjunction with applied science and manufacturing skills. But these days, manufacturing is being outsourced, and funding for pure sciences is being curtailed. With Bell Labs and other such idea factories disappearing, and with government research money endangered, what will propel innovation and job creation for the next 50 years?

Walter Isaacson
New York Times, April 8, 2012[1]

The capacity to innovate is fast becoming the most important determinant of economic growth and a nation's ability to compete and prosper in the 21st century global economy. Innovation encompasses not only research and the creation of new ideas, but the development and effective implementation of the technology into competitive products and services. Governments around the world now recognize that innovation, not just inputs such as capital and labor, is critical to sustaining economic growth, creating good jobs, and fulfilling national needs. Industrialized nations and emerging powers alike have boosted spending on research and development and unveiled comprehensive national strategies to build innovation-led economies. Indeed, just as the global

[1] Walter Isaacson writing "Inventing the Future" a review in the *New York Times* of April 8, 2012, of Jon Gertner's book *The Idea Factory – Bell Labs and the Great Age of American Innovation*.

movement toward freer markets in the 1990s became known as the Washington Consensus, the second decade of the 21st century is witnessing the emergence of what may be called the Innovation Consensus.

At the same time that the rest of the world is investing aggressively to advance its innovation capacity, the pillars of America's innovation system are in peril. America's public research universities are facing severe financial constraints. High budget deficits and public debt are exerting extraordinary pressure on federal and state lawmakers to cut spending on the very things that made the United States the world's innovation leader in the post-war era—and that are needed to keep the U.S. economy competitive and productive.

Policymakers are being forced to make painful choices about funding for universities, applied-research programs, help for small business, and new energy technologies. While other nations race to build state-of-the-art transportation systems and ubiquitous high-speed broadband networks, America's critical infrastructure suffers from a lack of sustained investment needed to match rising world standards. Failure to invest in these areas threatens to inflict long-term damage to America's innovation ecosystem, and therefore to its economy and security.

Formulating policy to shore up competitiveness is complicated by the fact that the United States is one of the few industrialized nations whose policymakers have traditionally not thought strategically about the composition of the nation's economy. America's international competitiveness is based on its capacity to innovate and manufacture new services and high-technology products. While innovation is often thought to result from the operation of a free market, in fact the government plays an instrumental role through its investments in R&D, as well as through policies that foster the commercialization of new ideas.

Since World War II, U.S. science and technology policy has been conducted under the assumption that federally funded basic research will be translated by the private sector into commercial products and new U.S. industries. Indeed, sometimes this transfer to the private sector does occur as expected. In many other cases, such as with nuclear power, computers, semiconductors, and aerospace, early government support and procurement has proved critical to the development of new industries. But the popular mythology that the American economy has thrived for decades under solely a *laissez-faire* tradition and linear approach to innovation policy tends to discount both the complexity of innovation and the vigorous government role in the development and deployment of new technologies. It is not just policies directly addressing the development and deployment of new technologies but also policies concerning tax, trade, intellectual property, education and training, and immigration, among others that play a role in innovation. In an age where Internet content is increasingly important to the economy, a broad range of skills is needed to secure American capabilities in innovation and competitiveness.

Whatever its source, America's preeminence no longer can be taken for granted. New players that regard innovation as a matter of strategic importance

are on the rise. Many governments are seeking to adapt the best features of America's innovation ecosystem, such as close collaboration between universities and business, public and private pools of risk capital, and programs that encourage researchers to start up their own companies.

Most other industrialized nations also are taking strong measures to bolster industries in which they are or wish to be competitive and to gain the benefits of jobs and growth afforded by established or emerging high-tech industries. In this highly competitive environment, the U.S. needs, once again, to devote policy attention and resources to the process of innovation because our future competitiveness as a nation is at stake. This commitment is needed if high paying jobs in sufficient numbers are to be created and if America's security is to be assured. The U.S. must understand and urgently address the underlying factors that may be weakening industries in which we might well compete.[2] The world of innovation is undergoing rapid and significant change, and America must change with it if the nation is to continue to prosper.

But what exactly should a national innovation policy look like and aim to achieve? In its essence, innovation is the alchemy of transforming ideas into new goods, services, and processes. Fortunately, the United States remains very strong in innovation as it is generally referred to—having ideas that have economic value to the inventors and in many cases other social value. Yet to create substantial value for the U.S. economy, policy must seek to achieve more than to encourage discovery and invention. America's tremendous investments in research and development cannot just be seen as a global public good. The fruits of innovation should translate into new marketable products, companies, industries, and jobs—and better living standards for Americans. There was a time when the proximity of U.S. companies' production to U.S. researchers was sufficient to give U.S. companies a big advantage that made speed less critical. Modern information and communications technologies have greatly reduced the significance of proximity, and many countries are taking actions to increase the pace of innovation.

Understanding how this process works—and how it can be advanced with public policy—is no simple task. The transformation of ideas into economic value occurs within adaptive networks of people and institutions that interact in complex, often ad-hoc ways. National "innovation ecosystems" typically include universities, private enterprises, public agencies, pools of investors, and national laboratories. Cultural norms and policy frameworks condition and shape interactions within and among these organizations. What's more, the innovation process can no longer be confined within geographic boundaries. Globalization has ushered in a swiftly evolving new paradigm of

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[2] Chapter 6 of this report addresses America's global competitive standing and policy approach in emerging high-technology industries including advanced batteries, next-generation photovoltaics, flexible electronics, and pharmaceutical and bio-medical products.

borderless collaboration among researchers, developers, institutions, and entrepreneurs spanning the world.

Many nations and regions have developed strategies to commercialize and industrialize technological advances. These efforts demand attention from American policymakers. By investing in extensive applied technology programs, for example, Germany and Taiwan have remained successful export manufacturers in advanced industries despite relatively high labor costs. European nations such as Finland and Belgium have demonstrated the power of public-private partnerships. Through its steady investments in education and infrastructure, Singapore is seeking to raise the bar of what it takes to compete in knowledge industries. India is demonstrating how to drive economic growth and exploit its intellectual capital by becoming an integral node in international innovation networks—largely through creating the necessary human resource base and avoiding excessive regulation of this entrepreneurial activity. The sheer ambition and scale of China's investments in science, technology, and next-generation industries, as well as its less laudable interventions, seek to redraw the map of the global economy.

STATEMENT OF TASK

The global economy is characterized by increasing locational competition to attract the resources necessary to develop leading-edge technologies as drivers of regional and national growth. One means of facilitating such growth and improving national competitiveness is to improve the operation of the national innovation system. This involves national technology development and innovation programs designed to support research on new technologies, enhance the commercial return on national research, and facilitate the production of globally competitive products. The Board on Science, Technology, and Economic Policy (STEP) proposes to study selected foreign innovation programs and compare them with major U.S. programs. The analysis, carried out under the direction of an ad hoc Committee, will include a review of the goals, concept, structure, operation, funding levels, and evaluation of foreign programs similar to major U.S. programs, e.g., innovation awards, S&T parks, and consortia. This analysis will focus on key areas of future growth, such as renewable energy, among others, to generate case-specific recommendations where appropriate. The Committee will assess foreign programs using a standard template, convene a series of meetings to gather data from responsible officials and program managers, and encourage a systematic dissemination of information and analysis as a means of better understanding the transition of research into products and of improving the operation of U.S. programs.

The first step toward understanding the implications for public policy of these global trends is to inform ourselves about the new nature of global competition for human and financial capital—not only between and within companies but also between governments.[3] To this end, the Committee on Comparative National Innovation Policies (CIP) of the National Research Council's Board on Science, Technology, and Economic Policy (STEP) convened a series of symposia from 2006 through 2011 examining select innovation policies and programs of different nations and comparing them to those of the United States. These conferences brought together leading government officials, industrialists, academics, researchers, and economists from advanced and emerging nations. The mission was to learn about national strategies designed to meet the new competitive challenges of the 21st century global economy and to identify best practices of private and public programs to strengthen industries, advance new technologies, and meet critical national needs.[4] It is important to note that the Committee did not seek to quantify the impact of these national strategies and programs. Nor did it seek to directly compare them with each other, recognizing that these policies and programs combine different levels of resources and organizational forms to seek different sets of outcomes within the contexts of different national innovation systems.

Participants at these conferences addressed topics that included the future of the solar power and advanced battery industries, the issues and opportunities associated with the rise of China and India, successful applied-technology and commercialization programs in Europe and Asia, regional innovation cluster strategies, and the role of such early-stage finance programs as the U.S. government's Small Business Innovation Research (SBIR) program.

The National Research Council has recently conducted a number of studies of U.S. competitiveness. Of particular note are the 2007 report *Rising Above the Gathering Storm*[5] and a follow-up report published in 2010.[6] The *Gathering Storm* reports focused heavily on the inputs into America's innovation system, such as K-12 science and math instruction, the supply of scientists and engineers, and federal research funding. The report also included a series of recommendations to address these deficiencies.

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[3] In multinational companies such as IBM, American workers often compete against Indian, Chinese, and other employees that work in their offshore R&D and manufacturing facilities.

[4] The National Academies Board on Science, Technology, and Innovation (STEP) has underway a study examining Best Practices in State and Regional Innovation Systems across the United States. The study is reviewing the practices and policies of particular regions as well as the synergies between federal, state, and regional efforts to build high tech clusters of competency and growth.

[5] National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic future*, Washington, DC: The National Academies Press, 2007.

[6] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Rising Above the Gathering Storm, Revisited: Rapidly Approach Category 5,* Washington, DC: The National Academies Press, 2010.

This report—the product of a series of international conferences, review of the work of the National Academies and similar institutions, and extensive discussion within the Committee on Comparative National Innovation Policies—by contrast, focuses on the outputs of the innovation process. This volume seeks to increase the understanding of the challenges the U.S. faces in converting new ideas into new commercial products, companies, industries, and jobs. While it endorses the findings of the *Gathering Storm* reports, the emphasis is on policies and programs that can generate more economic value out of the discoveries and inventions that flow from American taxpayers' substantial investments in research.

LIMITATIONS OF THIS STUDY

A report of this nature necessarily has limits to its scope. Recognizing this early on, the Committee chose to focus on a limited set of countries and an illustrative set of industries in its review. No single report can cover the full range of issues and technologies on this complex topic.

Choice of Countries and Regions: As noted in the Statement of Task, the purpose of the study is to take a selective review of important (notably China, India, and Germany) as well as noteworthy policy initiatives (e.g., Flanders) to develop national innovation capacity and industrial competitiveness. The intent is not to present an all encompassing overview such as those produced by the OECD but to highlight major developments and national strategies and consider their implications for the United States. The selection of countries was also driven by the willingness of leading policymakers, industrialists, and academics in these countries to engage with the Committee in an in-depth dialogue on these issues.

Choice of Sectors: The Committee also could not look at all sectors in adequate depth, within the necessarily limited scope of the study. It chose to focus on advanced manufacturing because it serves to illustrate a broad set of major challenges facing the U.S. in a highly globally competitive sector. We are aware that the report does not provide an in-depth discussion of very large and important sectors such as bio-medicine, aeronautics, and services, where the U.S. continues to set the technological pace.

OVERVIEW OF THE BOOK

This volume draws together our findings from this extensive study while also drawing upon existing research concerning the global competitiveness challenge and the policies and programs that drive it**.** The report is in two parts. Part I describes the role of innovation in addressing the competitiveness challenge and highlights key policies and programs that leading nations and regions are undertaking to address this challenge. Part I concludes with the Committee's consensus findings and recommendations. Part II of this report provides supporting data, including in-depth case studies of policies and

programs being promulgated in leading nations and regions of the world to accelerate innovation, grow new industries, and foster knowledge-based economic growth. The Overview at the front of this volume draws together the key points.

Part I: The Innovation Challenge

Chapter 1 describes the policies implemented around the world and the rapidly changing competitive landscape, reviewing the challenges they present to America's technological leadership and our ability to convert research and invention into economic value in the form of new products, companies, industries, and jobs.

Chapter 2 reviews the wide range of innovation policies adopted by other nations and regions, as well as by U.S. states, to attract, retain, and nurture the innovative industries of today and tomorrow. It identifies key trends in foreign programs and contrasts them with the erosion of existing U.S. strengths.

Chapter 3 sets out the Findings of the Committee.

Chapter 4 sets out the Recommendations, the consensus view of the Committee concerning steps the U.S. needs to take to address the challenges and opportunities in research and innovation that the United States faces in the 21st Century.

Part II: Global Innovation Policies

Chapter 5 provides case studies on several major emerging markets (China and India), successful industrializing nations and regions (Singapore and Taiwan), and more mature industrialized nations (Germany, Japan, the Flanders region of Belgium, Finland, and Canada). Despite their wide differences in terms of economic models and levels of development, the striking commonality among the strategies adopted by these nations is that they have adopted national innovation policies that often reflect the influence of U.S. practices, such as greater encouragement for universities to work with industry and incentives to spin off companies.

Chapter 6 of this report addresses America's global competitive standing and policy approach in emerging high-tech industries. Our case studies are of advanced batteries, next-generation photovoltaic cells, semiconductor manufacturing, and pharmaceutical and bio-medical products. In each of these sectors, the U.S. has been at or near the forefront in terms of innovation and/or the creation of promising start-ups. Translating this advantage into globally competitive industries that create high-paying jobs and drive economic growth, however, is a challenge that the United States must effectively address. The case of semiconductors illustrates that U.S. policy can play a role in restoring and preserving the competitiveness of a critical innovation-intensive industry. The studies of the advanced-batteries and photovoltaic products assess policy

strategies and options for bolstering U.S. competitiveness in these promising industries.

Chapter 7 addresses the policy instruments adopted by countries and regions around the world and across the U.S. to rise to the challenges of building innovation-led economies. One method is through the research parks with universities or national laboratories at their nucleus. The chapter explains how new research parks in the U.S. and abroad are adapting to the demands and opportunities of the 21st century global economy. The second part of this chapter analyzes regional innovation cluster initiatives around the U.S. It also explains the evolving role of the federal government in advancing regional innovation clusters. Case studies include bold and innovative initiatives in upstate New York, southeast Michigan, northern Ohio, South Carolina, West Virginia, and New Mexico.

Caveat: A few words are in order on the nature of this report. Our purpose in looking at other countries' innovation systems was to draw some useful lessons for the shaping of U.S. policy. Our intended audience is Congress, Executive Branch agencies, and all those interested in shaping U.S. policies that affect innovation.

Each country examined is markedly different from the United States—for example, Germany is the about the size of one and a half California's, China and India are at very different stages of development—but each offers insights into the thinking of policymakers as to what they think will be most effective to spur innovation. It is through observation of other's policies in this globalized world that the Committee members have informed their views as to what adjustments should be considered in U.S. policies.

The challenges and opportunities being created by the worldwide drive for innovation have never been greater in terms of jobs, income distribution, and ultimately competitive strength and the health of the U.S. economy. There is no single program or legislative enactment that will assure complete success; indeed, there is no panacea. But we are able to identify a series of steps necessary to improving the country's outlook in these regards. It has been said that the right thing to do is often hard but seldom surprising.[7] America has great competitive strengths. It is our conviction that if the steps outlined in this report were adopted, our country's future would indeed be brighter.

The responsibility lies fully with the Committee for the recommendations contained in this report.

ACKNOWLEDGEMENTS

This Report would not have been possible without the collaboration with numerous scientific academies, scholars, technology company executives,

[7] Adam Gopnik in the *New Yorker*, April 9, 2012, on Albert Camus, in an essay entitled "Facing History" about in part editorials that Camus wrote for *Combat* a resistance newsletter.

and public officials at home and abroad. It also depended heavily on the volunteer efforts of CIP Committee members over an extended period of time. In particular, special appreciation is due to Bill Spencer, the chair of the Committee during the initial conferences. Special recognition is due to Pete Engardio, formerly of *Businessweek*, for his drafting and reportorial skills. His ability to synthesize a vast amount of material was essential for a report of this scope. William Noellert deserves our special thanks for his review of data and economic analysis, as does Thomas Howell for his many substantive contributions. Both were important to the scope and quality of this report. This project would not have occurred nor have been brought to its final report stage without the leadership, knowledge of national and international programs, and organizational skills of Dr. Charles Wessner. The commitment and support of his team at the National Academies, including in particular Dr. Sujai Shivakumar, has been central to the production of this report, as have the efforts of David Dierkshiede, McAlister Clabaugh, and David Dawson for the many international conferences that characterized this effort. This report would also not have been possible without its initiation by the STEP Board and the encouragement given to it by the Board and the National Academies, as well as the prior and ongoing work of the Academies on which this report builds.

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Acknowledgement of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and

responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the process.

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Christopher Hill, George Mason University, and Granger Morgan, Carnegie Mellon University. Appointed by the National Academies, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

FUTURE WORK PROGRAM

The international competition in innovation is increasing. Globalization has accelerated the pace of change. There is much to be learned from and about foreign measures and policies that will shape the U.S. economy, the nation's security and the well-being of the U.S. workforce. Best practices should be considered for adoption. Measures of foreign governments and entities that distort international competition must be examined and responses crafted. There is much to be gained from international cooperation with respect to global challenges in energy, climate, and health, among others. It is the strongest recommendation of the Committee that that an ongoing work program to address these needs and opportunities be put into place.

To this end, the National Academies Board on Science, Technology, and Economic Policy will establish a new Innovation Policy Forum. The purpose of this forum is to act as a focal point for national and international dialogue on innovation policy. The Forum will bring together representatives from government, industry, national laboratories, research institutes, and universities—foreign and domestic—to exchange views on current challenges and opportunities for U.S. innovation policy and to learn about the goals,

instruments, funding levels, and results of national and regional programs and discuss their lessons for U.S. policy and potential impact on the composition of the economy.

Alan Wm. Wolff
Chair, Committee on
Comparative National Innovation Policies