Meeting Global Challenges: U.S.-German Innovation Policy

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Charles W. Wessner, Rapporteur; 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

MEETING GLOBAL CHALLENGES
German-U.S. Innovation Policy

SUMMARY OF A SYMPOSIUM

Charles W. Wessner, Rapporteur

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

Alan H. Anderson
Consultant

McAlister T. Clabaugh
Program Officer

Sujai J. Shivakumar
Senior Program Officer

David S. Dawson
Senior Program Assistant

David E. Dierksheide
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Preface

Recognizing that a capacity to innovate and commercialize new high-technology products is increasingly a part of the international competition for economic leadership, governments around the world are taking active steps to strengthen their national innovation systems. These steps underscore the widely held belief that the rising costs and risks associated with new potentially high-payoff technologies, and the growing global dispersal of technical expertise, require national R&D programs to support new and existing high-technology firms within their borders.

What is the impact of these initiatives for the competitive position of the United States? In a recent report, the National Academies warned that "this nation must prepare with great urgency to preserve its strategic and economic security," adding that "the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring."[1] Reinforcing this message, a new report by the National Academies describes the growth in foreign programs and investments in new technologies and industries while noting the decline in support at home for the traditional pillars of U.S. competitiveness.[2] The report urges steps to ensure that products derived from U.S. innovation are manufactured in the United States, so as to capture the economic activity and the high-quality jobs that they can bring.

Understanding the policies that other nations are pursuing to support their industries and to what effect is essential to understanding how the nature and terms of economic competition are shifting.[3] U.S. policymakers would

[1]National Academy of Sciences/National Academy of Engineering/Institute of Medicine, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future,* Washington, DC: The National Academies Press, 2007, p. 4.

[2]National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, C. Wessner and A. Wm. Wolff, eds., Washington, DC: The National Academies Press, 2012.

[3]The Woodrow Wilson Center's Kent Hughes has argued in this regard that the challenges of the 21st century require new strategies that take account of new technologies, new global competitors, as well as new national priorities concerning national security and the environment. See Kent Hughes,

benefit from knowing of the wide variety of innovation and competitiveness policies that leading nations have adopted. In the case of Germany, these innovation policies support industrial production and technology research through consistent investments in applied research programs buttressed by programs for job training and worker retention. German organizations such as the Fraunhofer Institutes partner with companies to turn advanced technologies into production processes and commercial products. These initiatives are coupled with active export promotion support from the highest level of government.

THE OVERALL PROJECT

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 formal Statement of Task for the overall project states: Recognizing the importance of targeted government promotional policies relative to innovation, the Board on Science, Technology, and Economic Policy (STEP) is studying selected foreign innovation programs and comparing them with major U.S. programs. This analysis of Comparative Innovation Policy, carried out under the direction of an ad hoc Committee, includes a review of the goals, concept, structure, operation, funding levels, and evaluation of foreign programs designed to advance the innovation capacity of national economies and enhance their international competitiveness.

This analysis focuses 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 CONTEXT OF THE PROJECT

Since 1991, the STEP Board has undertaken a program of activities to improve policy makers' understanding of the interconnections among science, technology, and economic policy and their importance to the American

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Building the Next American Century: The Past and Future of American Economic Competitiveness, Washington, DC: Woodrow Wilson Center Press, 2005, Chapter 14.

economy and its international competitive position. The Board's interest in comparative innovation policies derives directly from its mandate.

This mandate has previously been reflected in STEP's widely cited study, chaired by Gordon Moore of Intel, on how government-industry partnerships can support the growth and commercialization of productivity enhancing technologies.[4] Reflecting a growing recognition of the importance of the surge in productivity that occurred in the mid-nineties, the Board also launched a multifaceted assessment, exploring the sources of growth, measurement challenges, and the policy framework required to sustain what was then characterized as the information and communications technology driven New Economy.[5]

The current study on Comparative Innovation Policy builds on STEP's experience to bring together leading academics, public officials, business representatives, and policy experts from around the world to identify current trends and challenge faced by U.S. and foreign innovation programs.

PROJECT ACTIVITIES

To open its analysis, the study Committee held an overview symposium that drew together leading academics, policy analysts, and senior policymakers from around the globe to describe their national innovation programs and policies, outline their objectives, and highlight their achievements.[6] Major conferences in Taipei and Tokyo focused on the evolution of the Taiwanese and Japanese innovation systems over the past decade.[7] The Committee also convened a major conference in Washington that identified current trends in the Indian and U.S. innovation systems and highlighted the emerging U.S.–India innovation partnership.[8]

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[4]This summary of a multi-volume study provides the Moore Committee's analysis of best practices among key U.S. public-private partnerships. See National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2003. For a list of U.S. partnership programs, see Christopher Coburn and Dan Berglund*, Partnerships: A Compendium of State and Federal Cooperative Programs,* Columbus, OH: Battelle Press, 1995. See also National Research Council, *U.S. Industry in 2000: Studies in Comparative Performance*, David Mowery, ed., Washington, DC: National Academy Press, 1999.

[5]National Research Council, *Enhancing Productivity Growth in the Information Age: Measuring and Sustaining the New Economy,* Dale W. Jorgenson and Charles W. Wessner, eds., Washington, DC: The National Academies Press, 2007.

[6]For a summary of this conference, see National Research Council, *Innovation Policies for the 21st Century—Report of a Symposium*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007.

[7]For a summary of the Tokyo conference, see National Research Council, *21st Century Innovation Systems for Japan and the United States: Lessons from a Decade of Change*, S. Nagaoka, M. Kondo, K. Flamm, and C. Wessner, eds., Washington, DC: The National Academies Press, 2009.

[8]For a summary of this conference, see National Research Council, *India's Changing Innovation System: Achievements, Challenges, and Opportunities for Cooperation*, Charles W. Wessner and Sujai J. Shivakumar, eds., Washington, DC: The National Academies Press, 2007.

This was soon followed by a symposium on "Synergies in Regional and National Innovation Policies in the Global Economy" hosted by Flanders Vice Minister Fientje Moerman. This event reviewed the synergies and success of regional innovation policies in Flanders, buttressed by national and European Union programs. Flanders benefits from major university and research centers with strong commercialization records, and is also home to imec, one of the leading microelectronics research facilities in the world and arguably the flagship of Flemish technology policy.[9] To address a growing opportunity in U.S. S&T cooperation with Europe, the Committee hosted a series of meetings to review the potential for greater U.S.-Polish cooperation in science and innovation, with particular attention to traditional energy sources (e.g., coal) and health. In a related effort, a major international symposium was convened to review national strategies to foster the development of science and technology research parks, with representatives from around the world.[10]

In light of China's surging investments in science and new technologies, a number of meetings on China's innovation policies were convened, beginning with a symposium in May 2010 in Washington, DC, on *U.S.-China Cooperation on Science, Technology, and Innovation* that drew together speakers primarily from the U.S. and Chinese governments and academia.[11] This was followed in June 2011 with a series of meetings in Shanghai and Beijing that included U.S. and Chinese corporate leaders and leading Chinese academic researchers. These interactions were capped by a September 2011 symposium in Washington, DC, on *U.S.-China Policy for Science, Technology, and Innovation.*

Germany's renewed focus on investments in R&D and education, worker retention and training, as well as its strong support for exports suggest opportunities for mutual learning and expanded cooperation. Accordingly, the Committee convened in 2010 a conference in Washington, DC, on *Meeting Global Challenges: German-U.S. Innovation Policy*. A second large conference was then organized in cooperation with the German Institute for Economic Research (DIW) in Berlin in 2011. This volume summarizes that conference. It examined U.S. and German approaches to support innovation and manufacturing both in terms of institutional support (e.g., by the Fraunhofer Institutes) and in specific sectors such as bio-medical, electric vehicle and solar technologies.

These two conferences highlighted the value of policy dialogue and cooperation on innovation for Germany and the United States. Both countries

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[9]National Research Council, *Innovative Flanders: Innovation Policies for the 21st Century—Report of a Symposium*, C. Wessner, ed., Washington, DC: The National Academies Press, 2008.

[10]This report has garnered considerable national and international attention. See National Research Council, *Understanding Research, Science, and Technology Parks: Global Best Practices—Report of a Symposium*, C. Wessner, ed., Washington, DC: The National Academies Press, 2009.

[11]For a summary of this conference, see National Research Council, *Building the 21st Century, U.S.-China Cooperation on Science, Technology, and Innovation—Summary of a Symposium,* C. Wessner, rapporteur, Washington, DC: The National Academies Press, 2011.

seek to better translate research into innovations and innovations into successful products. Further, both countries can benefit through cooperation in addressing the "grand challenges" we face today, including those in climate, energy production, health, and security. The conferences underscored the opportunity for Germany and the United States to learn from each other and to gain by cooperating more actively with each other.

Drawing together the information and insights from this series of meetings, the Committee developed a consensus report that provides an overview of the changing international environment and offers a wide range of recommendations to support more effective U.S. innovation policies for the future.[12]

THIS WORKSHOP SUMMARY

This report captures the presentations and discussions of the 2011 Berlin symposium on *Meeting Global Challenges: German-U.S. Innovation Policy*. It includes an introduction highlighting key issues raised at the meeting and summary of the meeting's presentations. This summary has been prepared by a rapporteur as a factual summary of what occurred at the workshop. The planning committee's role was limited to planning and convening the workshop. The statements made are those of the rapporteur or individual workshop participants and do not necessarily represent the views of all workshop participants, the planning committee, the DIW, or the U.S. National Academies.

ACKNOWLEDGMENTS

On behalf of the National Academies, we express our appreciation and recognition for the insights, experiences, and perspectives made available by the participants of this meeting. We are greatly indebted to Klaus Zimmerman of IZA (the Institute of the Study of Labor) and then head of the DIW-Berlin, for his leadership and initiative as well as to Jens Schmidt-Ehmcke, who played an instrumental role in the organization of the conference and the identification of the many high-level German participants.

We are most grateful for the support and participation of U.S. Ambassador Murphy and his able staff and to Englebert Beyer of the Federal Ministry of Education and Research (BMBF) for his leadership, support, and substantive contributions to this cooperative German-American event.

We would like to express our thanks to Alan Anderson for preparing the initial overview and summary of the meeting in a very short timeframe. We also thank Sujai Shivakumar and David Dierksheide of the STEP staff for their work on the review and production of this report and recognize the efforts of

[12]National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, C. Wessner and A. Wm. Wolff, eds., op. cit.

McAlister Clabaugh and David Dawson for their assistance in organizing this international conference.

ACKNOWLEDGMENT 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 quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: David Audretsch, Indiana University; Erik Lehmann, Augsburg University; Andreas Pinkwart, HHL-Leipzig Graduate School of Management; Jens Schmidt-Ehmcke, Hasso Plattner Ventures Management; and Klaus Zimmerman, University of Bonn.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. Responsibility for the final content of this report rests entirely with the rapporteur and the institution.

Alan Wm. Wolff Charles W. Wessner

I

OVERVIEW

Overview

While nations have always competed for territory, mineral riches, water, and other physical assets, they compete most vigorously today for technology-based innovations and the value that flows from them. Much of this value is based on creating scientific knowledge and transforming it into new products and services for the market. This process of innovation is complex and interdisciplinary. Sometimes it draws on the genius of individuals, but even then it requires sustained collective effort, often underpinned by significant national investments. Capturing the value of these investments to spur domestic economic growth and employment is a challenge in a world where the outputs of innovation disseminate rapidly. Those equipped to understand, apply, and profit from new knowledge and technical advances are increasingly able to capture the long-term economic benefits of growth and employment.[1]

In response to this new, more distributed innovation paradigm, the National Academies Board on Science, Technology, and Economic Policy (STEP) convened leading academics, business leaders, and senior policymakers from Germany and the United States to examine the strengths and challenges of their innovation systems. More specifically, they met to compare their respective approaches to innovation, to learn from their counterparts about best practices and shared challenges, and to identify cooperative opportunities. The symposium was held in Berlin and organized jointly by the German Institute for Economic Research (DIW) and the U.S. National Academies with the support of the German Federal Ministry for Education and Research (BMBF) and the American Embassy in Berlin.

Both U.S. and German participants described common challenges on a wide variety of issues ranging from energy security and climate change to low-emissions transportation, early-stage financing, and workforce training. While recognizing their differences in approach to these challenges, participants on

[1]See National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, Charles W. Wessner and Alan Wm. Wolff, eds., Washington, DC: The National Academies Press, 2012.

both sides drew out valuable lessons from each other's policies and practices. In his opening remarks, Gert Wagner of the German Institute for Economic Research (DIW Berlin) predicted that the symposium would help identify best practices in stimulating innovation in key industries, as well as in suggesting areas where the two nations might cooperate in the future.

Participants were also aware of the need to adapt to a new global environment where many countries have focused new policy measures and new resources to support innovative firms and promising industries. "We all need to pay attention to what the rest of the world is doing," commented Alan Wolff, Chair of the National Academies' study of Comparative National Innovation Policy. "The policies of others shape the environment in which we cooperate and compete.""In fact," he added, "there is not a country disinterested in innovation policy. They are all working hard to capture value in the 21st century."[2]

SUSTAINING U.S.-GERMAN COOPERATION

Sustaining strong U.S.-German relationships in trade, investment, and science was seen as important to sustaining the innovative strengths of both countries. As German Minister of State Werner Hoyer noted at the symposium, the United States is Germany's most important trading partner outside the European Union, and Germany is the U.S.'s leading trading partner in Europe. While the 2008 global economic crisis "slowed trade between the two nations, transatlantic trade has been increasing again since 2009. Bilateral trade amounted to $130 billion in 2010, up from $115 billion in 2009." The figures of foreign direct investment are also robust. In 2009, German companies invested an accumulated $334 billion in the United States, the second-largest amount by an EU country, behind the Netherlands. Germany was the fifth-largest foreign investor in the United States with investments of $116 billion. Citing these developments, Dr. Hoyer observed, "We see that the transatlantic relationship has come a long way since the Marshall Plan." Today, he said, the United States and the European Union are the world's most closely linked economic regions, jointly generating 54 percent of the world's GDP and providing 30 percent of its consumers.

In his keynote remarks at the symposium Philip Murphy, U.S. Ambassador to Germany observed that both countries have a long history of robust, bilateral scientific and technological investment. The United States and Germany have announced similar targets of investing more than three percent of GDP in public and private research and development. These investments in basic and applied research create incentives for private investments in

[2]For a review of innovation policies of leading nations and the challenges facing the United States, see National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*, Charles W. Wessner and Alan Wm. Wolff, eds., op. cit.

Box A
Sharing Best Practices

Participants at the symposium identified many concrete areas where Germany and the United States can share best practices in innovation policy, such as funding initiatives, intellectual property rights, peer review, scientific exchange, public-private partnerships, and the role of NGOs. "It seems meaningful to ask: What is the state of affairs?" said Georg Schütte, Germany's State Secretary for Education and Research. "How can we compare them? What can we learn from each other?"

innovation. In both countries, the universities, federal labs, and industrial laboratories conduct research that ultimately leads to breakthrough products and new companies. German and American counterparts work closely together to foster research and innovation. The Fraunhofer Institutes, for example, have seven research centers in the United States, and the Max Planck Society now has a Center for Bio-Imaging in Tampa, Florida. There are more than 50 bilateral cooperation agreements between individual institutions on topics ranging from earth sciences to energy physics to public health.

As strong and productive as this relationship has been, Ambassador Murphy said, it is desirable to reinforce and expand both long-standing and more recent connections. The relationship was given a more formal structure through a science and technology agreement signed by the two countries on February 10, 2010, which establishes a framework for further cooperation. The objective is to continue to identify and intensify relations in education and research, to coordinate joint research teams, and to interlink shared national priorities in science policy to the benefit of both sides.

Speakers from both the United States and Germany emphasized the importance of cooperation and mutual learning in the area of innovation policy. According Minister of State, Dr. Hoyer, the "complexity of global challenges means that cooperation and competition in innovation go hand in hand." In addition, he said that both the United States and Germany "must give priority to research, science, and education." "Only an innovation-friendly climate and technological progress will allow for sustainable growth, employment, and prosperity." At the same time, speakers from both countries also recognized unresolved challenges on many issues, including energy security, carbon capture and sequestration, costs of solar energy and battery technology, smart grids, electromobility, patenting, technology transfer, and network neutrality.

Furthermore, as Carl Dahlman of the Georgetown University School of Foreign Service told the symposium audience, Germany and the United States now share a "demanding, dynamic, and uncertain global environment" with big new players and many possible uncertainties, from another financial crisis to

An innovation culture depends also on the wealth of people, their openness to new ideas, and their willingness to take risks, said Dr. Gert Wagner of DIW Berlin. "Only an open-minded and tolerant society can support sufficient innovative talent to allow the economy to grow rapidly."

internal problems disrupting China. "The world is in tremendous flux, with big challenges, and big constraints. This talk is an invitation to our North Atlantic alliance to better collaborate in rebalancing our global systems."

Given these challenges, State Secretary Schütte highlighted the common need on both sides of the Atlantic to communicate the sense of urgency to the governing electorate and general public: "If we share a consensus that education, research, and development are so important, how can we convince our political representatives? How can we convince the public that it is important, despite the need for fiscal restraint, to spend more money in this area than in other areas?"

ONGOING BILATERAL COLLABORATIONS

A rationale for collaboration mentioned by several participants is to combine American and German strengths in addressing challenges beyond the reach of either nation alone. These challenges could include:

- Mitigation of environmental pressures.
- Preparation for pandemics.
- Improvement of energy efficiency and develop alternative energy technologies.
- Development of CO_2 sequestration.
- Mitigation of diseases of aging populations.
- Promotion of natural resource technologies.
- Mitigation of social risk and instability.

The degree of U.S.-German cooperation in science and technology is "huge," declared Seth Winnick, Counselor for Economic Affairs at the Embassy of the United States in Berlin. Each invests heavily in the other's innovation systems, and in a wide range of research, development, and innovation topics. And both countries have set the common objective of investing more than 3 percent of GDP in public and private research and development. In both countries, the universities, federal labs, and industrial laboratories conduct research that leads to breakthrough products and new companies. German and American counterparts work closely together to foster research and innovation.

Describing the scope of cooperation, Mr. Winnick noted that German and U.S. institutions share more than 50 bilateral agreements in R&D areas

ranging from earth sciences to energy physics to public health.[3] Echoing Ambassador Murphy, he noted that in February 2010, Germany and the U.S. signed their first umbrella science-and-technology agreement and signed memoranda of understanding in the fields of energy and cancer research.[4] Also, the U.S.-German Framework Agreement on Scientific and Technological Cooperation, concluded in 2009, adds a strategic component to bilateral cooperation. Through the Transatlantic Economic Council (TAC), founded in 2007 on a German initiative, the United States and EU cooperate on future-oriented economic issues, including e-mobility.[5] Finally, said Mr. Winnick, the two countries signed a "significant S&T cooperation agreement" in 2010, which will be implemented over several years.

Ongoing collaborations are taking place in several areas of priority to both nations. Some of these were described by Ambassador Murphy and Minister of State Hoyer at the symposium.

Cooperation on Renewable Energy:

Ambassador Murphy noted that the United States formally joined the International Renewable Energy Agency, or RENA, on March 4, 2011. In Germany, the Bonn Innovation Center for Renewable Energy opened in 2011. The United States will be a partner in the development of clean technologies at the Bonn Center. The U.S. National Renewable Energy Laboratory (NREL) in Colorado has collaborated since 2008 on solar research with three institutes of the Helmholtz Association. The partners are seeking to broaden the range of their research through a new MOU focusing on solar photovoltaic materials and systems, including solar fuels and concentrated solar power (CSP), as well as performance and reliability. The Fraunhofer Institutes also opened a Center for Sustainable Energy Systems in Cambridge, Massachusetts, several years ago.

Ambassador Murphy offered two recent examples of commercial-scale collaboration. First, the world's largest onshore wind energy park, located on former cotton farmland in Texas, is owned and operated by the German energy company E.ON. This huge generator, the Rock Hill Wind Farm, has 600 wind turbines capable of generating over 780 Mw of electricity. The second example is the decision of the world's second-largest photovoltaics manufacturer, First Solar, a U.S.

[3]For a comprehensive explanation of bilateral cooperation in science and technology, see Federal Ministry of Education and Research, "Germany and the United States Increase Their Cooperation," March 24, 2011 (<*http://www.bmbf.de/en/6845.php*>).

[4]See also the presentation of John Holdren at November 1, 2010, National Academies Symposium on "Meeting Global Challenges," held in Washington, DC.

[5]See the summary of the presentation by Engelbert Beyer, in the Proceedings chapter of this volume.

company, to site its main manufacturing plant in Frankfurt on der Oder.[6]

Cooperation on Complex Hardware:

Dr. Hoyer noted that another area with substantial partnerships is the development and use of complex hardware. This includes U.S. participation in the German electron synchrotron (DESY), the large hadron collider at CERN, and a joint project linking the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory in Tennessee with the Neutron Spin Echo Spectrometer at the Technical University of Munich. The opening of the Max Planck Florida Institute in Jupiter, Florida, which focuses on bio-imaging, is another milestone in U.S.-German cooperation. There is also further bilateral cooperation on the International Space Station and the Stratosphere Observatory for Infrared Astronomy, as well as other basic research projects in physics, health, energy, and civil security.

Cooperation on Academic Exchanges:

The two countries also support several academic exchange programs. According to Dr. Hoyer, the German Foreign Office funds exchanges and scholarships that enable American students and scientists to visit Germany. The Foreign Office also operates the German Center for Research and Innovation in New York, which it established in 2010 in the federal Ministry of Education and Research. Dr. Hoyer described it as a "cornerstone of the German government's strategy for international science and research."

Cooperation on Security Challenges:

Dr. Hoyer added that both countries would be preparing for possible new security challenges in the 21st century, such as asymmetric threats and the larger menace of terrorism. "A U.S.-German agreement on cooperation in civil security research was signed in March 2009, designed to produce mutual benefits on issues such as visual analytics, cargo security, and detection of hazardous substances." Similar collaboration is under way in climate change research.

Dr. Hoyer emphasized that stronger cooperation with the United States "is part of the German government's strategy for the internationalization of science and research." The central purpose is to address the challenge of global competition, especially from newly competitive powers, notably China. "And this is going to be the hour of

[6]Frankfurt on der Oder, or Frankfurt (Oder), is located in eastern Germany on the Oder River, which forms the German-Polish border.

truth," he said, "because the dynamics of development in other parts of the world is overwhelming. If we do not meet these challenges, if we do not interest our young people in science and technology, we are going to lose the technological leadership positions we still have."

CHALLENGES IN THE GLOBAL ECONOMY

Speakers from both countries took note of the changes in the global economy, particularly the steadily increasing competition generated by China, India, Korea, Taiwan, and other emerging powers. "In almost all types of advanced technology, it is American research centers and enterprises that are leading," said State Secretary Schütte. At the same time, he said, the United States is challenged to maintain this leadership as it recovers from the recent economic crisis and faces new competitive pressures.

In his symposium presentation, Mr. Wolff noted that China is actively seeking to foster "indigenous innovation," though increased support for university research and development, national laboratories, universities, science and technology parks, and a defensive IP environment. Current goals include intensive investments in crucial high-technology products, and the use of policy tools to draw in foreign technologies and promote indigenous innovative technologies, increase R&D spending to 2.5 percent of GDP by 2010, and support state projects to generate important strategic products.[7]

Dr. Carl Dahlman of Georgetown University pointed out in his presentation, this strategy brings difficulties for potential partners by forcing the use of Chinese standards, Chinese parts, skewed procurement, Chinese branding, and local purchasing mandates. At the same time, the rapid growth of China and other emerging economies poses important opportunities. Citing IMF data for growth rates of the eight largest economies from 2000 to 2010, Dr. Dahlman reported "a strong indication that in terms of purchasing power parity, China's economy will surpass that of the United States around 2016." India's economy, he said, will move into third place, passing Japan, and continue its own climb at a slightly slower rate than China. "Both China and India face big challenges," he said, "and history is not linear. But both China and India are becoming large players on world scene, and are likely to become larger and more important over time."[8]

In terms of China's outputs from 1998 to 2008, the volume of science and engineering articles rose from near zero to about 60,000, surpassing Japan and Germany. The same pattern is seen for patent applications. While the

[7]For a review of Chinese innovation policies, see National Research Council, *Building the 21st Century: U.S.-China Cooperation in Science, Technology, and Innovation—Summary of a Symposium*, C. Wessner, rapporteur, Washington, DC: The National Academies Press, 2011.
[8]See Carl Dahlman, *The World Under Pressure: How China and India Are Influencing the Global Economy and Environment*, Palo Alto, Stanford University Press, 2011.

quality of these publications and patents vary, Dr. Dahlman noted that the Chinese are making a very big effort, "going from a focus on imitation, which they have done well, to tapping global knowledge, to beginning to innovate on their own account."

China has also rapidly built up its workforce. According to a report of the National Academies, China produced about 2,000 PhDs in science and engineering fifteen years ago; this figure rose to 22,000 by 2007. In the United States, the number of graduating PhDs rose from 17,000 to 23,000 over the same period.[9] Another part of China's effort to strengthen human resources has been to recruit overseas scientists and engineers, especially expatriate Chinese, by offering generous job opportunities.[10] According to Klaus F. Zimmermann of the DIW Berlin, this "global tug-of-war" for talent will take on increasing importance for both Germany and the United States, which is accustomed to near-automatic access to the best students from around the world. "Whoever wins the battle for manpower," he said, "will be the victor in the 21st century."[11]

KEY FEATURES OF THE U.S. INNOVATION SYSTEM

State Secretary Schütte characterized the U.S. innovation system as generally more productive and "disruptive" than that of Germany. He noted that the U.S. success with cutting-edge technologies is closely linked to several factors, beginning with the leadership of major research universities. A second factor, he said, is entrepreneurial spirit, which leads to success in new business models. A third factor for success has been the United States' ability to attract the best talent from around the world. A fourth strength is its generally efficient capital markets, particularly the availability of venture capital and other risk capital. Finally, he said, technological success is supported by government investments in R&D, which are "markedly higher than in Germany and Japan." These factors combine to create opportunities for disruptive innovations that are "significantly greater than in Germany and Europe."

Several participants highlighted the American "entrepreneurial culture" as a key feature of the U.S. innovation system. Noting that American culture places high social value on commercial success, Thomas Curran of Deutsche Telekom AG said that the early entrepreneurs and industrialists of the United States were regarded as "heroes" and were the first "globalizers of industrial

[9]National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, *Is America Falling Off the Flat Earth?* Washington, DC: The National Academies Press, 2007.

[10]For a review of Chinese policies to attract Chinese born scientist and engineers back to China, see National Research Council, *Building the 21st Century: U.S.-China Cooperation in Science, Technology, and Innovation—Summary of a Symposium*, C. Wessner, ed., op. cit.

[11]See Amelie F. Constant, Bienvenue N. Tien, Klaus F. Zimmermann and Jingzhou Mengl, "China's Latent Human Capital Investment: Achieving Milestones and Competing for the Top," Bonn: IZA Discussion Paper 5650, September 2010.

Box B
Federal Support for Small Business Entrepreneurship

A key U.S. federal mechanism to promote the formation and survival of small, technology-based firms is the Small Business Innovation Research (SBIR) program. This program has several advantages. It is stable, having been in place for 25 years, and, as a set-aside mechanism, has no budget line, thereby providing a steady source of funding, allocating 2.5 percent of each federal agency's R&D budget to small business awards and contracts.[12] Speaking at the symposium, Charles Wessner of the National Academies noted that total SBIR spending by agencies is about $2.5 billion a year, large enough to achieve a significant "portfolio effect" through a diversity of topic areas. Other key advantages are that SBIR grants and R&D contracts do not have to be paid back, a company retains complete control of its intellectual property, and approval by SBIR often creates a "certification effect" that raises the perceived value of awardees' firms, helping to attract outside investors.[13]

thinking." In the 1960s through 1980s, the United States continued to generate many successful entrepreneurs, buttressed by a strong belief in technological change and a market eager for new products. In this regard, Ginger Lew, then of the National Economic Council, noted that creating an environment conducive for entrepreneurship was a key element of U.S. innovation policy, adding that in terms of policy, the country prefers to promote innovation with a "light touch."

In his symposium presentation, John Fernandez, then Assistant Secretary of Commerce, said that U.S. innovation depends on three basic building blocks: people, ideas, and infrastructure. First, innovation is possible only through the actions of a skilled and talented work force. For this reason, he noted, strengthening the U.S. work force is a key element of the Obama administration's strategy for technology and innovation. The second building block, he said, is continued investment in basic research to accelerate the knowledge breakthroughs that mark the beginning of the innovation cycle. The third building block is modern infrastructural networks, including the smart grid, next generation air traffic control, new wireless communications systems, and

[12]This amount was authorized in 2012 to increase to 3.1 percent by 2017. At the recommendation of the National Academies, based on a study led by former Defense Under Secretary Jacques Gansler, the legislation reauthorizing SBIR raised the standard size of individual grants from $100,000 to $150,000 for Phase I projects and from $750,000 to $1 million for Phase II projects. See National Research Council, *An Assessment of the SBIR Program*, C. Wessner, ed., Washington, DC: The National Academies Press, 2008.
[13]See National Research Council, *An Assessment of the SBIR Program*, op. cit.

other networked systems that move people, energy, and ideas with speed and efficiency.

Several participants also described some of the challenges facing the US innovation system including flat or declining U.S. investments in R&D. By contrast, public R&D investment has surged in Asia, with expenditures of the Asia-8 economies surpassing those of the EU-27 in 2003, and approaching those of the United States in 2010, the last date for which figures are available.[14] At a time of growing R&D expenditures overseas, this has meant that the U.S. share of global R&D has declined. In addition, as Charles Wessner pointed out in his presentation, much of federal R&D spending is defense-oriented and skewed towards weapons systems development rather than fundamental discovery. The defense R&D budget totals $82 billion and accounts for about 55 percent of federal R&D spending, with about 90 percent of that spent on weapons systems development.[15]

RECENT U.S. INITIATIVES

Since the Obama Administration took office in 2009, the federal government has taken several steps to support innovation. Philip Singerman of NIST noted that this support is reflected in the president's budgetary commitment, the statutory authority issued through the bi-partisan America COMPETES legislation, and the enhanced role of NIST, particularly its support for manufacturing through the Manufacturing Extension Partnership.

Ginger Lew, formerly of the National Economic Council, described the push by the Obama Administration for greater coordination among the federal research agencies charged with ensuring that small and medium-sized enterprises (SMEs) in the nation's regions, states, and municipalities have the incentives, support, and resources they need to bring new products and services to the marketplace. She also drew attention to *Startup America*, an initiative launched by the White House in January 2011 to promote entrepreneurship across the country. Startup America is investing $2 billion to help entrepreneurs by lowering barriers to high-potential, fast-growing small companies, especially in high-tech fields such as clean energy, nanotechnology, biotechnology, and advanced manufacturing. Another new program, the *Task Force on Advancing Regional Innovation Clusters* (TARIC), was designed to encourage federal agencies to collaborate more effectively in advancing the growth of regional innovation clusters in the United States. These innovation clusters have the objective of forming public-private partnerships at many levels, and providing resources, linkages, and infrastructure to SMEs.

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[14]National Science Board, *Science and Engineering Indicators 2011*, Arlington, VA: National Science Foundation, 2011. Access at <*http://www.nsf.gov/statistics/digest12/start.cfm*>.
[15]See National Research Council, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy,* op. cit., pp. 30-31.

Secretary Fernandez noted that the Economic Development Administration (EDA) launched the *Jobs and Innovation Accelerator Challenge* in May 2011. This initiative, he said, is a joint effort of 16 federal agencies designed to promote growth through public-private partnerships in at least 20 pilot regions across the country that demonstrate high-growth potential. This program builds on the success of an earlier pilot project, the *Energy Regional Innovation Cluster* (ERIC), launched in 2010. As Ms. Lew noted in her remarks, ERIC provides about $130 million from seven federal agencies to create a regional research center, develop new building efficiency technologies, and cluster the work of local partners to implement these technologies in local businesses and buildings.

In his presentation, Jerry Lee of the National Cancer Institute (NCI) said that his organization is seeking to use new research and analytical tools and new ways of thinking to understand the mechanisms causing cancer. This initiative grew out of the *1000 Genomes Project,* specifically a request by NCI to the research community asking what they most needed to "conquer cancer." Dr. Lee noted that the researchers responded by saying that they wanted more data, they wanted it publicly available, and they wanted it in "real time." In turn, he said, NCI responded by placing unprecedented amounts of information in the public domain.

Dr. Lee added that NCI also responded with innovative ways to use the data: to make a systematic identification of all cancer genomic changes, repeat the identification for all cancers, and make it publicly available. A new *Cancer Genome Atlas* was launched for brain, lung and ovarian cancers, with data on every patient who came through the program. As a result of this initiative, he said, a possible resistance mechanism inside the disease has been discovered; it was discernible because of the unprecedented availability of data.

NCI then wanted to "do something more complex; to really understand the system, and try to predict it using all this new data," noted Dr. Lee. "We thought the best way to do that is to bring in another point of view, and when it's a hard problem, we always turn to the physicists." NCI recruited some 300 physicists from outside with high interest in looking at this problem, and established the *Physical Sciences Oncology Network* "to build the infrastructure that can better understand and control cancer through the convergence of physical sciences and cancer biology. We envision a future where individualized medicine becomes a reality—individualized, targeted cancer care."

THE GERMAN INNOVATION SYSTEM

Germany's innovation system differs from that of the U.S. in several fundamental ways. While the U.S. has more of an entrepreneurial economy, explained Engelbert Beyer of the Federal Ministry of Education and Research (BMBF), the German model is more oriented toward "solid, high-quality progress" that is anchored in existing industries. Whereas labor and skilled talent move relatively freely in the U.S., mobility is more limited in Germany. In

terms of federal science and technology policy, programs are dispersed across many agencies in the United States. In Germany, the Federal Ministry of Education and Research (BMBF), has a broad portfolio that includes most federal R&D activities that promote commercialization, while the Federal Ministry of Economics and Technology (BMWi), also has a range of technology and innovation programs.

Innovation in Germany therefore tends to be incremental rather than "disruptive," added Dr. Beyer. Funding is directed predominantly to traditional industries—automobiles and parts, chemicals, pharmaceuticals, machinery, and engines—and serves to integrate newer technologies into these industries, to develop and integrate these areas into system products, and to develop high technology in a step-by-step manner. As one consequence, he said, Germany is relatively weak in the ICT sector, but strong in the automotive sector. Germany has barely any profitable Internet platforms, but is developing the Internet of "things," the cyber-physical systems.

Dr. Beyer said that the "innovation rhetoric" differs in Germany as well. In the United States, it is generally believed that government should play a limited role in industry and commerce. In Germany, "it is quite common to refer to government as a problem solver." In his remarks, Dr. Rainer Jäkel of the Federal Ministry of Economics and Technology (BMWi) agreed that the German government has no qualms about providing "cradle to grave" financial assistance for R&D and commercialization efforts by small- and medium-sized enterprises in the case of "market failure" by private lenders. "The government has the right to intervene," he said. "It is well known that the banks are not so supportive."

Germany's federal government also promotes innovation through support for scientific research. "Government funding for science, research, education, and innovation was set to rise by €12 billion between 2010 and 2013."[16] The objective, Dr. Jäkel said, "is to invest 10 percent of GDP in research and education by 2015—3 percent in research and 7 percent in education. With research and development amounting to 2.8 percent of GDP in 2009, Germany already ranks among the world leaders in this respect."

He added that Chancellor Angela Merkel's government has increased investments in R&D, which rose by one-third to €12 billion ($17.1 billion) from 2005 through 2008. Germany spent €80 billion in economic stimulus during the financial crisis, followed by a further €11 billion in stimulus that went to education and science and technology. Coming at a time when other nations were cutting back in the face of recession, the major commitment to innovation represented "a paradigm shift of some importance" for Germany, explained Dr. Jäkel.

[16]See European Commission, *Innovation Union Competitiveness Report, 2011: Country Profile-Germany*.

Germany's innovation system is characterized by heavy corporate and government investment in research, innovative small and medium-sized enterprises, extensive workforce training, and strong institutions, such as Fraunhofer-Gesellschaft that collaborate with Germany industry. The government also works to assure that the nation is a "lead market" for important, emerging technologies through methods such as consumer incentives, government procurement, and standards.[17]

According to Dr. Zimmerman, an emphasis on manufacturing and exports has served Germany well over the past few years of global turbulence. The government's response to the 2008-2009 global financial crisis and recession highlights the importance that Germany places on preserving its manufacturing sector. In the U.S., manufacturers laid off workers, who then sought public unemployment benefits. Germany, by contrast, subsidized manufacturing salaries so that staff could stay on payrolls while working part time. As a result, consumer spending and service industries remained robust through the recession. When recovery came, German exporters were able to quickly increase production and gain market share.

According to David Audretsch of Indiana University, the strength of the German innovation system is the Mittelstand, which are small and medium sized enterprises locally known as Germany's "hidden champions." Dr. Audretsch explained that these enterprises are not so much "hidden" as specializing in certain niche markets, often becoming world leaders by maintaining very high levels of quality. "You get a sense of stable, long-term small and medium-sized firms that don't come and go as they do in America." The Mittelstand are often owned by the same family for two, three, or even more generations, sustaining a long-term orientation.

Even so, Dr. Jäkel cited research by Germany's Center for European Economic Research (ZEW) showing that the vast majority of Germany's SMEs spend little on regular R&D.[18] He noted that the ZEW has cited the difficulty of raising funds for R&D from banks as a major reason. Much of the country's R&D is confined to a few sectors, notably automobiles and parts, accounting for more than one-fourth of the total; machine tools; electrical engineering; chemistry; and a few others. A positive outcome, however, is that much advanced technology developed in these industries finds its way to uses in traditional areas.

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[17]A "lead market" is a regional market that can establish the early commercial success of an innovation and large-scale production, increasing the chances of global diffusion. A discussion of Germany's strategy of establishing a lead market in photovoltaic cells and other technologies can be found in Klaus Jacob, et al, "Lead Markets for Environmental Innovations," *ZEW Economic Studies*, Volume 27, Heidelberg: Physica-Verlag, 2005.

[18]See for example, Klaus Borger, et al, *Mittelstand Monitor, 2005: Annual report on cyclical and structural issues relating to small and medium-sized enterprises,* Frankfurt am Main: KfW Bankengruppe, 2005.

As Dr. Jäkel and others pointed out, the German innovation system does face some serious challenges. These include a scarcity of venture capital and bank loans for innovative companies, declining momentum in sectors such as electronics and aircraft, and weak performance in eastern Germany and Berlin, which consume a large share of federal research spending but produce relatively little innovation. In addition, the states have been weakened by recession, so that the whole burden of financing innovation improvements falls on the federal government. In the words of Engelbert Beyer, "It is not self-evident that you can continue the huge increases in financing research and education in the public sector." Some speakers also pointed out that Germany ranks below most other industrialized nations in researchers as a percentage of total employment, measures of international collaboration in research, and venture capital as a percentage of GDP. There are fears of a looming skills shortage due to declining university enrollment as the population ages and German youth show less interest in science and technology.

NEW GERMAN INITIATIVES

Several speakers highlighted new initiatives by Germany's federal government that complement its strong support for education and basic and applied research. The federal government commits €10 billion to higher education and €2 billion to the German National Science Foundation, a doubling over the past decade. In addition, the German government makes significant contributions to the Fraunhofer Gesellschaft (Europe's largest applied research organization with an annual budget of 1.65 Euros), the Helmholtz Association (a community of 18 scientific-technical and biological-medical research centers with an annual budget of 3.4 billion Euros), and the Leibnitz Association (comprised of 86 institutes conducting application-oriented basic research and providing scientific infrastructure with an annual budget of 1.4 billion Euros.)[19]

A major federal initiative is the High-Tech Strategy of 2020. Its main objective is to bring together not just the ministries related to economics, transportation, environment, and others in one forum; the new element of the High-Tech Strategy 2020 for Germany was a clear approach toward mission-oriented policies. This approach broke with the past in an important way. Fifteen or 20 years earlier, innovation policy often consisted simply of identifying "this little market failure or that one, and fine-tuning it here or there," said Dietmar Harhoff. "We're coming now to an overarching view of the system, not just the externalities and market failures. It's about coordination, communication, and maybe even about strategies."

[19]See the websites of these organizations for additional details of their mission, structure, and budgets. <*http://www.fraunhofer.de/en.html*>; <*http://www.helmholtz.de/en/*>; and <*http://www.leibniz-association.eu/*>.

The strategy invests €6 billion in R&D and €6 billion more in education. "We had a large consensus from all the major parties," said Dr. Jäkel, "that our future depends on innovation, research, development, and education, and that this is not the moment to economize." The goal of the High-Tech Strategy, said Frauke Lohr, Senior Partner at Grolman, is to help create and nurture markets, deepen and broaden the cooperation between science and industry, and foster innovation as a basis for national health and well-being.

An ambitious program of the federal government is the Morgenstadt, or "Tomorrowtown," which is part of the High-Tech Strategy. The program is designed to prepare for future challenges, beginning with patterns of living, especially in the cities. While urban areas cover only about 1 percent of the earth's surface, they generate 75 percent of global energy demand and about 80 percent of greenhouse gas emissions, primarily carbon dioxide. By the year 2050, approximately 70 percent of the world population will live in cities. The Tomorrowtown plan describes major features of life in the future, including energy, transportation, living patterns, spaces, and governance. Future energy supply is described as both safe and cheap, as are smart traffic management systems. The plan, to be used for planning and policy purposes, is supported by the Industry-Science Research Alliance and many others.

Finally, Joachim Giesekus presented a vision of innovation from the Fraunhofer Heinrich Hertz Institute (HHI), whose specialty is information and communications technology (ICT). In this case, Dr. Giesekus described an effort to convert the institute's expertise into products of value to biomedicine. HHI discovered "some raw diamonds that needed only some polishing," as he put it, "to move technologies we already had" into the medical device market. Working with private companies, the engineers of HHI have been adapting their work in multimedia, data processing, image processing, photonics, sensors, and data networks into applications for surgical practice, diagnosis, organ imaging, cancer detection, and other medical uses.

HUMAN RESOURCES, UNIVERSITIES, AND RESEARCH

Participants from both Germany and the U.S. expressed concern about insufficient numbers of skilled workers, education deficits, and demographic trends. For example, Jan Muehlfeit, Chairman Europe of Microsoft, saw education in the European Union and the United States as "lagging" as "new champions were emerging." He said that the Program for International Student Assessment, or PISA, is often won by the Finns, or by the Koreans. Last year, however, "students from Shanghai beat both groups by 30 points in every category. That is equivalent to about one year's advantage in reading, mathematics and science."

He also expressed concern that the European educational system did not promote innovation. When children are in kindergarten in Europe, he said, 90 percent of them would like to be innovators and entrepreneurs, doing "something outside their comfort zone." By the time they leave university, only

17 percent feel that way, and only 4 percent will actually attempt it. "That's because the old system," he said, "which is based on logic and memorizing, is not unlocking human potential."

An important feature of human resources in Germany is its tradition of apprenticeships, which strongly influences overall outcomes. According to Karl Ulrich Mayer, President of the Leibniz Association, at least 50 percent of four-year college degrees are not up to the cognitive standards that are imposed by apprenticeship exams after three and a half years. Still the proportion of people in Germany entering the labor market with a highly qualified vocational or professional degree is about 80 percent. In Germany, the custom is for high school graduates to spend 1.5 or 2 years as vocational trainees at a bank or a large company. This enhances their job preparation. In contrast, American employers often cannot identify a student's primary vocational skill. Engelbert Beyer affirmed that technical training in the form of apprenticeships "is obviously one of the underpinnings of the German economy," especially its high standing in engineering and technology.

At the same time, German participants expressed concerns not only about the quality of university education, noting that German research universities lag behind their counterparts in the United States. In terms of quantity, Dr. Beyer cited a DIW Berlin report that projects that Germany will have a shortfall of 270,000 skilled workers by 2020.[20] Georg Schütte cited a recent study by the Cologne Institute for Economic Research estimating that Germany's skills shortage costs the economy up to €20 billion a year, or one percentage point of GDP.

In his presentation, Leibniz's Dr. Mayer sought to balance the description of research and skills training in Germany. He noted that the relatively low ranking of German universities derives partly from the omission of the non-university components of the research and education sector. These consist of the Max Planck Society, the Fraunhofer Institutes, the Helmholtz Association, and the Leibniz Association. He also said that while more U.S. students enter universities, a higher percentage of German university students actually complete their degrees, and many others complete high-quality master's and diploma programs. "Then," he said, "Germany looks much better."

Other participants saw worrisome trends beyond the institutional level. Microsoft's Dr. Muehlfeit said that Germany was weak in attracting and retaining foreign talent, and would benefit from more determined efforts to do so. Initiatives, such as Canada's 'smart immigration' program, could serve as a model in this regard. In EU universities in general, he said, only 2.6 percent of students were non-European, which runs counter to global trends. "The mix of

[20]Comments by Engelbert Beyer at the National Academies conference, "Meeting Global Challenges," held on November 1, 2010, in Washington, DC.

cultures and the drive for innovation are missing here," he said. "In the United States, more than 50 percent of university students are non-U.S."

Dr. Zimmermann of DIW Berlin emphasized that people are more mobile today, and can work where conditions suit them. He foresaw an "enormous shortage of skilled workers" not only in Germany, but also for every country. And workers, he said, are the "driving force of innovation." In recent years, Germany has attracted many low-skilled workers, but very few high-skilled workers. "So Germany has the standing of a fortress," he said, "a country that does not want to attract high-skilled labor." He advocated new policies to welcome those with skills, such as a special passport. Dr. Beyer noted that the "current huge inflow of young people to German universities will stop at end of this decade, when numbers will decrease rapidly."

In response to such concerns, Germany created a Commission of Experts for Research and Innovation (EFI), which between 2006 and 2011 has completed four reports for Chancellor Merkel and the German government. "We pick our topics because we think they are important to the long-term, sustainable welfare and growth of Germany," said Dr. Harhoff, who chairs the EFI commission. EFI underwrites support for some 15 in-depth studies per year, and recommended higher spending on education even in 2008 during the recession. "Education," he said, "is innovation policy." The commission encourages better education mainly through incentives, which range from support for entrepreneurship to total funding of research and development projects.

A complementary program is the Excellence Initiative, which emerged in 2005 when the federal and state governments decided to use extra resources to give a few German universities a chance to close the gap with the best research universities worldwide. "This was a serious departure from Germany's basic tenet of equal distribution of resources," said Andreas Pinkwart, Dean of the Leipzig Graduate School of Management. Traditionally, the German science system spreads public financial support among every university.

The Excellence Initiative chose three lines of funding: (1) 39 graduate research schools, which would receive support for leading doctoral students; (2) 37 clusters of excellence; and (3) nine "elite universities" receiving up to €13.5 million. According to Dr. Mayer, this educational "jump-start" began with a publication of the National Science Council in 2000, which advocated more internationalization, stronger research, greater competitiveness, increased mobility, and increased investment by the federal government, states, and industry. It brought a new degree of competition into the system—"some people say too much."

"I had low expectations for this strategy," he said, "but what happened in the last 10 years is that the universities just turned around. If anybody had told me 10 years ago that German professors would spend their three-month summer vacations meeting to develop cooperative plans for research collaborations, I would have said they were crazy. But this is exactly what has happened." Other outputs included more published papers and publications, more spinoffs from

the research associations, and closer collaboration between research organizations and universities.

U.S. universities feel their own pressures, particularly in the form of budget cuts for public institutions and expectations that universities play a larger role in promoting economic growth. One public university, the University of Akron, in Ohio, has developed a new model that broadens the mission and image of the institution. In his symposium presentation, University of Akron President Luis Proenza noted that "Largely, we've tended to think of universities as producing human capital and some new knowledge. But in fact they generate many kinds of capital: creative capital, knowledge capital, human capital, social capital, financial capital, and natural capital." In short, he said, their "product portfolio" is much broader than the common perception. The University of Akron evolved over the last 140 years amid the rubber and polymer industry, and developed close ties with the larger economy. Today, he said, the University of Akron seeks to engage with its community, and understands that if the community is not successful, neither is the university. Among many initiatives over the past decade, the university has led a neighborhood enhancement program, partnered with economic development groups, hospitals, and businesses, and converted unused or "weak" assets, such as patents, space, retirees, and outdated libraries, into strengths. "It's a question of looking at the university not as a one- or two-product institution, but as a broad-based platform that can be both flexible and robust."

ENTREPRENEURSHIP, EARLY-STAGE FINANCE, AND STARTUP FIRMS

While the generation of new knowledge and innovations provides essential raw material for economic growth, new innovation-based firms require a supportive climate of people and financing. A broad and sometimes intangible range of customs, values, and laws can either encourage or dampen the entrepreneurial spirit. For example, as Charles Wessner pointed out, bankruptcy laws in the U.S. are structured in such a way as to lower the risks of entrepreneurship. When entrepreneurs fail, as some must inevitably do, these laws permit prompt recovery and reallocation of human capital.

Dr. Harhoff described what he called Germany's "underdeveloped entrepreneurial culture" observing that while the MP3 player was invented in Germany, MP3 technology generated in its peak year only about $100 million in licensing revenues, or less than 0.01 percent of the value added to the industry.

Eran Davidson, a venture capitalist in Germany, said that "our biggest constraint is the lack of entrepreneurs to start companies." This comment was amplified by several speakers who described Germans' "aversion to risk." As Peter Terhart of the German Private Equity and Venture Capital Association (BVK) put it, "Should I take the risk of establishing myself independently with my own firm, or should I go to Siemens or a successful 'hidden champion' where the salary and employment are secure?" The lack of venture capital and

concern about the risks of entrepreneurship may often persuade a young person to make the conservative choice, he said. "The culture here in Germany is not as tolerant of mistakes as it is in the United States. They don't dream as big."

Alexander Kritikos, DIW's Director for Entrepreneurship Research, expanded on the topic of risk, saying that the most successful entrepreneurs are those with a "moderate level of risk aversion." Entrepreneurs who are too risk-averse, he has found, have a higher likelihood of failure; those who are "too risk-loving" likewise show a high incidence of failure. Achieving a "moderate level" of risk, he said, should be a key goal of policy makers as they shape innovation policy and subsidies.[21]

Dr. Lew emphasized the central role of startup businesses in job creation, despite the risks involved. In the United States, she said, small firms created more than 40 million net new jobs in the past 15 years, or two out of every three new jobs. At the same time, the risk of starting a new firm is amplified by fiscal constraints. "In the distribution of federal regulatory costs," she said, "a disproportionately large share falls on small businesses. Very small firms, with fewer than 20 employees, fare the worst, spending 45 percent more per employee than large firms to comply with federal regulations."

Small firms face even more severe challenges in attracting early-stage financing. Despite the common belief that innovations by small firms will ultimately be recognized and supported, the reality is that potential investors have less than perfect knowledge, especially about innovative ideas, and this "asymmetric information" leads to suboptimal investments.

While early-stage capital is scarce in the United States, Dr. Kritikos observed that it is even harder to find in Germany. In 2010, German firms or individuals invested some €650 million in small firms and entrepreneurs. One reason cited at the symposium was that Germany does not have pension funds, omitting a dominant investor from the venture capital market. Banks have been the primary provider of venture funding, but this is not part of their core business, and venture funds from banks dried up in the recent downturn.

Dr. Harhoff agreed that venture capital "is really the bottleneck right now" for German startups, but said that the government had taken steps to provide more capital. In 2005, the BMBF formed a €272 million public-private partnership called the High-Tech Startups Fund. The fund can invest up to €500,000 in a new, promising company. The goal is to support young companies for up to two years, from the R&D stage through proof of concept and even market entry—by which time it is hoped that private financing will be available. In its first five years, the fund has pledged to take holdings in 177 technology companies.

[21]See Marco Caliendo, Frank Fossen, and Alexander Kritikos, "The Impact of Risk Attitudes on Entrepreneurial Survival," GfA Discussion Paper No. 12/2008.

In his remarks, Eran Davidson noted that his company, Hasso Plattner Ventures, is "trying to combine the two cultures into one," working with German companies, German entrepreneurs with American roots, American CEOs, and others. The objective is to meld the international cultures of the two countries to improve startup performance. After five years, the firm has invested in 20 companies, several of them profitable, with a portfolio of $82 million from five investors in the EU and United States.

In the United States, a portion of the Startup America initiative is dedicated to more effective early-stage financing, said Secretary Fernandez. Both the Angel Capital Association and the Angel Resource Institute have announced that they would double the number of high-caliber investors affiliated with angel groups across the country, increasing annual investments by more than $1 billion. Qualifying Startup America member companies would be matched with angel investor mentors to help grow their businesses. The National Venture Capital Association pledged to provide access to its 400+ venture capital firms, its 4,000-plus investors, and thousands of venture–backed companies' CEOs.

In Germany, a public-private partnership has been created with €240 million in state funds and €32 million in corporate funds to help young companies survive financially in their first year, especially high-tech companies. Dr. Jäkel noted that a Central Innovation Programme Mittelstand was launched in 2009 for "innovation consulting" and a small grant of €15,000, open to any field of technology. The companies learn in cooperation with Fraunhofers and others how to develop their business and how to collaborate in networks and clusters. Many universities now have entrepreneurship programs. In addition, bankruptcy laws have recently been changed to give people another chance when they have failed as entrepreneurs.

The German government is seeking to increase R&D by smaller companies by connecting them to federal research programs and through expanded financial subsidies. In 2008, several SME-related activities within the BMWi were consolidated into the Central Innovation Programme SME, known by its German acronym ZIM.[22] Normally, ZIM has an annual budget of around €300 million, but it received a major additional increase of €900 million through Germany's economic stimulus program in 2009 and 2010. ZIM's stated goals are to encourage SMEs to dedicate more efforts to innovation, reduce the risks of technology-based projects, and rapidly commercialize research.

Germany's tax policies are cited as a disincentive to investment. Accordingly, Germany cut its corporate tax rate from 38.65 percent to 29.83 percent in 2007, placing it near the median point of European economies, but the EFI Experts Commission notes that Germany is one of few industrial nations

[22]In 2008 and 2009, the programs PRO INNOII, INNO NET, NEMO, and INNO-WATT were restructured and integrated into Central Innovation Programme.

that do not offer a tax credit for R&D. The Experts Commission blames tax policies for falling R&D investment by small and medium-sized enterprises and the scarcity of private risk capital, and asserts that shortages of angel funding and venture capital could worsen unless Germany adopts an "internationally competitive, growth-promoting tax framework."[23]

TECHNOLOGY TRANSFER

Several speakers emphasized the weakness of technology transfer in both countries. Mr. Wolff said that the "single major gap in knowledge" for both the United States and Germany was "the right formula for transforming the benefits of innovation into high-quality jobs in large quantities. The challenge is to rediscover the alchemy of moving from innovation to strong domestic employment in an era of globalization."

Germany benefits from the public-private partnerships of the Fraunhofer-Gesellschaft, in which the needs of industry are connected to first-rate facilities and researchers. Despite its many contributions, Dr. Hoyer lamented Germany's inability to capitalize on its own innovations. Mr. Davidson agreed that "it invents so much and profits from its inventions so little." He displayed a chart of fundamental inventions made in Germany, including the light bulb in 1854, the telephone in 1859, the television in 1930, the maglev train in 1934, the computer in 1941, and the MP3 in 1987. "Guess what?" he said. "For all of those technologies and more, revenues are generated by American, Japanese, and recently Chinese companies."

Part of the reason, he said, was that in Germany, "perfection is valued with an almost religious fervor. Perfection in Silicon Valley, on the other hand, is likely to be regarded as time-consuming and inefficient. Longevity is important in Germany, where an idea must be assigned to a long-term plan of at least 20 years. In Silicon Valley, quick wins are important. A culture of thinking dominates Germany, while Silicon Valley has a culture of just doing." Finally, he said, in Germany the managers tend to be engineers, while in the United States, managers are business-oriented people. "Marketing is the dominant theme of every company: marketing, marketing, marketing."

ENERGY

Symposium participants held extensive discussions on energy, especially on the goals of energy security and the development of a low-carbon economy. Dr. Charles Ebinger of the Brookings Institution observed that the issue of climate change draws little interest from most U.S. voters, and that the

[23]German Institute for Economic Research data cited in Juliane Kinast, Christian Reiermann, and Michael Sauga, "Labor Paradox in Germany: Where have the Skilled Workers Gone?" *Spiegel Online*, June 22, 2007.

debate over energy had narrowed to a focus on jobs rather than environmental or efficiency concerns.

By contrast, the issues of energy and climate change resonate deeply with many German voters. The most spirited discussions of the symposium concerned Germany's decision to phase out its nuclear plants and work toward an all-renewables energy policy by 2050.[24] Dr. Ebinger noted that with the exit of Germany, and constraints on U.S. nuclear construction, China is now poised to become the "global vendor" of nuclear plants, and "is now building the best coal plants, moving toward carbon capture and sequestration, and building the largest renewable installations as well."

Dr. Hüttl noted that "getting out of nuclear" is not as simple as "just shutting down the power plants." It requires a means of safe waste disposal, which is not yet available, and the desire to retrieve nuclear waste once there are technologies to treat it safely. In her roundtable remarks at the conference, Ms. Kotting-Uhl of Germany's Green Party agreed that a nuclear phase-out would require additional research on safety, and the reactors in operation would still run for another decade or more before they could be safely dismantled.

Nonetheless, Ms. Kotting-Uhl argued that aside from minimal research in winding down the nuclear sector, however, virtually all energy research funding should be dedicated to applied research on renewables. She opposed any further funding for nuclear fusion on the grounds that greater efficiencies and the use of renewable sources would make it unnecessary.[25]

Dr. Rossman, a representative of the Social Democratic Party (SPD), questioned whether it is sensible to "completely step away" from fundamental research, including nuclear energy research, saying that his party favored a broad portfolio of fundamental work. "We believe we should not exclude insights that can become important in a more distant future." He did agree that the best way to build energy security and reduce foreign dependencies was "to steer Germany toward renewable, decentralized energies by 2050 in the most economical and efficient way."[26]

In her comments, Dr. Arati Prabhakar, then a partner with U.S. Venture Partners, raised the point that renewables and other "clean tech" solutions faced a fundamental barrier: lack of sufficient financing. "If we don't have adequate capital to deploy these technologies," she said, "all the R&D investment and

[24]Following the Fukushima Daiichi accident in Japan, the German government decided to shift energy demand away from nuclear power. "Germany plans to shut its remaining nine reactors by 2022 and raise the share of renewables to at least 35 percent of the power mix by 2020. It's the biggest overhaul of the nation's energy infrastructure since World War II." Bloomberg News, "Germany Will Publish Progress Report on Nuclear Exit in December," July 24, 2012.
[25]Sylvia Kotting-Uhl, Member of the Bundestag, Green Party; Member, Committee for Education, Research, and Technology, symposium presentation, Berlin, May 24-25, 2011.
[26]Ernst Dieter Rossman, Member of the Bundestag, Social Democratic Party; Member, Committee for Research, Education, and Technology, symposium presentation, Berlin, May 24-25, 2011.

VC/private equity will be no more effective than pushing on a noodle." She noted that VC firms entered this area with a burst of enthusiasm, but that the energy industry itself moves very slowly, given the huge infrastructure in place. Competitive pressures on the VC industry, she said, cause many firms to avoid clean technologies that might require expensive factories in favor of less capital-intensive business opportunities, such as energy efficiency or IT-like products that are not manufactured.

Dr. Karsten Neuhoff, Director of the Climate Policy Initiative-Berlin, addressed the question of whether Germany had invested too much in solar energy. He observed that German progress in this area had also inspired China to raise its goals for solar deployment, "which created a general good. So yes, sometimes you have to take a first step; you might benefit yourself, but also contribute quite a bit to development elsewhere. It's really about gradually evolving the system, and I think we are in a world where we can learn from each other in this process."

Dr. Ebinger noted that the International Energy Agency projects that the world is still going to derive about 85 percent of its energy from fossil fuels in 2050, even if Germany meets its targets for renewables. He said that Germany, as a great technological nation, could make valuable contributions to energy science, including CCS from coal and natural gas. "If we don't solve those problems," he said, "it doesn't matter what else we do about climate change."

The Green Party's Kotting-Uhl replied that Germany's best contribution to the global energy effort is to be a "model and exemplar. I think that there has to be a country, among the highly-industrialized, which shows, first, economic standards and exports and success; secondly, a high quality of life; third, climate protection; and, fourth, a nuclear phase-out. Germany is on track to model all these features."

The SPD's Mr. Rossman agreed that Germany should take "a true international perspective, enabling all countries to share the most modern technological options to develop what they need. The alternative is to advise them to take the path of large coal and nuclear plants. This cannot be a development perspective, and is why renewable energy should be the priority. We should serve as a model for these countries that renewables represent a secure, tradable energy supply, providing for mobility, health, and education in every country."

CLIMATE CHANGE AND CO_2

In contrast to the political inaction on climate change at the national level in the United States, Germany has an aggressive national policy organized

around the EU roadmap for moving to a low-carbon society by 2050.[27] This roadmap includes 2020 targets of reducing greenhouse gas emissions by 20 percent compared to 1990 levels and cutting primary energy use by 20 percent through efficiencies and the use of renewables. The specific targets for 2050 are more ambitious, and very close to a no-carbon economy. They call for an 80 percent reduction in greenhouse gas emissions, hastened by CO_2 restrictions, improved energy efficiency, intelligent city planning, and hybrid engine technologies. Germany's Roadmap 2050 calls for expenditures by 2020 of €100 billion for smart grids, €25 billion for insulation, and €50 billion for sustainable mobility.

For carbon capture and sequestration (CCS), Germany faces strong local resistance. A central problem, according to Dr. Hüttl, is that despite the identification of a safe disposal site below capstone formations, "there is no acceptance for this technology here in Germany. People think CCS is dangerous, like nuclear waste."

On the positive side, added Dr. Hüttl, "climate change itself is an important driver of new technologies and innovation." Hence, the research being done on mitigation and adaptation holds potential value for many related activities. He also described a "long-term interrelation" between innovation and sustainability, with innovation enabling sustainability through new products and processes, and sustainability in turn driving innovation through global challenges.

ELECTROMOBILITY

In developing the vehicles and infrastructure for battery-powered transportation, both nations share a desire to be leaders. Germany plans to have 1 million electric cars on its roads by 2020, a goal regarded by many as ambitious. Germany will promote its industry through subsidies, tax exemptions, and R&D funding, said Dirk Arnold, an electromobility expert, though it counts on "competition as the best incentive for innovation. We can't do anything without industry. We need them to focus the whole effort."

In the United States, a substantial challenge to the electric vehicle industry is battery pricing, which is now about $650/kWh. The goal is $300/kWh by 2014, and ultimately $150/kWh. "We need higher-performing

[27]It is important to note that many state and local governments in the United States are addressing climate change, even in the absence of the federal government's participation in the Kyoto Protocol. Although many of the state and local initiatives are unlikely on their own to have a big effect on mitigating global climate change, some policies, such as California's recently proposed standards for greenhouse gas emissions from passenger vehicles, do have the potential to significantly reduce U.S. emissions. Collectively, these small and large distributed efforts could "result in U.S. emissions reductions of approximately 1 to 1.5 percent below "business as usual" by 2015-2020." See Kristen Engel, "Mitigating Global Climate Change in the United States: A Regional Approach," *NYU Environmental Law Journal,* 14: 54, 2005.

basic chemistry," said Ed Owens of the U.S. Department of Energy. The United States projects 1.2 million electric vehicles by 2015, but even this figure will represent only 0.4 percent of the nation's vehicle fleet. One problem is the high up-front cost of an electric vehicle—even though the total cost of ownership is low. "Hybrids are already economically viable," said Mr. Owens, "but consumers tend to focus on first cost." Additional challenges for both countries, said Dr. Hüttl, are energy storage and grid integration.

BUILDING SOLAR INDUSTRIES

Both the U.S. and Germany have ambitious hopes of increasing energy independence through solar generation of electricity. Germany has become a leader in deployment of rooftop solar panels, spurred largely by its national feed-in tariff (FIT) program. This program is both stable and successful at increasing demand in the marketplace. The negative aspect is the cost to the ratepayer, but many are willing to bear it.

The German FIT has been effective at stimulating the solar industry, resulting in global demand leadership. Rooftop photovoltaics (PV) are a central pillar of the Climate Policy Initiative, said to be capable of producing about one-quarter of German electricity. The continuing challenge is cost, which is gradually decreasing through both technical and organizational innovations.

For the United States, a PV panel still costs about twice as much to put on a roof as it does in Germany, making it difficult to offer a fixed price, and capacity far exceeds demand. Both countries are challenged to find the right balance between too much support for R&D and too little. With too little support, the industry lags; with too much support, it is difficult to ensure that an innovative design can compete. Government does have a responsibility to reassure investors that demand will continue to grow over at least next three to four years. "This demand," said Dr. Neuhoff, "is still going to be policy driven before the technology is cost-competitive at the wholesale level."

Unlike Germany, the United States relies heavily on the 30 percent R&D investment tax credit to push PV innovation; it also uses the advanced manufacturing tax credit and loan guarantee programs. While these programs are helpful, said Dr. Minh Le of the U.S. Department of Energy, they are not sustainable. "The private sector needs to take over if this sector is to expand," he said.

The total amount of VC and private equity financing deals in 2010, he said, totaled about $2.3 billion. About three-quarters of those deals were done in the United States, whose very strong venture capital community has been an engine for innovation. This is an important first link of the value chain, he said, but it is not sufficient. "Debt financing and asset financing will be required for this industry to expand much more widely than it is today." Of the $44 billion in solar debt financing world-wide in 2010, the United States held only a 9 percent market share, and it has only 7 percent of the world market share of PV cells and modules.

Dr. Le said that a 75 percent reduction in cost is needed for the U.S. industry to be competitive. In the United States, the cost of residential solar installation was approximately $6.50 a watt in 2010. In Germany, it was approximately $3.80 a watt. “Given that the cost of PV modules is the same worldwide,” he said, “what’s really different is the balance of systems, especially installation and permitting costs.”

Many secondary support mechanisms for both manufacturing and demand are fairly similar in the two nations. The favored mechanism to incentivize demand in the United States is the renewable portfolio standard (RPS), which has been adopted or planned by 30 states. “If we can reduce solar costs by a factor of three or four by the end of the decade,” he said, “we can play an important part in meeting President Obama’s clean electricity standard of 80 percent by 2035.” Progress is held back, he said, by the trillions of dollars in energy assets already deployed.

Dr. Neuhoff noted that if Germany were to stop its PV support programs, financial participants would also stop their support, “and within a few months we would have cash flow issues across the sector. We would lose a lot of the capacity that was carefully built up and that might contribute both to global PV development and to German economic success. You need to maintain the momentum if you want to play in the game.”

MUTUAL OPPORTUNITIES

A frequent theme of the symposium was that Germany and the United States face common innovation challenges, and that they thus have common opportunities to address them in partnership. In particular, Minister of State Hoyer noted the need to develop renewable energy, improve energy efficiency, and safeguard their nations from terrorism and other asymmetrical threats. “We are more likely to succeed if we combine our resources and technology.”

He also noted the complexity of those challenges. “Achieving prosperity for all in the face of limited resources, the challenges of climate change, energy security, food security—no one nation can address these challenges on its own,” he said. “The more closely we work together, the more likely we are to find solutions. In a climate of healthy competition, Germany profits from U.S. prosperity, and vice-versa.”

By forging common strategies, he added, both countries gain in expertise, and in the synergies of complementary approaches. The approaches differ, for example, in areas such as risk management, tax policy, incentives for renewal energy, and application of federalism to national energy policy. And while Germany has decided to phase out nuclear power, the United States intends not only to continue operation of its existing nuclear fleet, but also to resume building new plants. Germany has relied on market-based mechanisms to innovate, especially the feed-in tariff, and the aggressive use of tax policy and gasoline taxes to incentivize efficiency.

In his remarks, Ambassador Murphy noted that the two nations have long recognized the value of collaboration, and the desirability of sharing their abundant resources. He recalled that then candidate Barack Obama noted in his Berlin address of July 2008, "While the 20th century taught us that we share a common destiny, the 21st has revealed a world more intertwined than any time in human history." Echoing this sentiment, Ambassador Murphy noted: "As the world's pre-eminent manufacturing and innovation centers, Germany and the United States can not only set an example by growing their own economies; they can also advance technological know-how and innovative developments that grow the global economy and serve the greater international community."

Indeed, as Jens Schmidt-Ehmcke of the DIW Berlin observed of the symposium: "We learned from each other's programs, compared tools, and discussed best practices. Our innovation systems are different, as are the roles of the governments. However, both nations share similar goals and challenges."

II

PROCEEDINGS

DAY 1

Welcome

Gert G. Wagner
Chairman, Executive Board
German Institute for Economic Research (DIW Berlin)

Dr. Wagner opened the symposium by welcoming participants on behalf of the German Institute for Economic Research (DIW Berlin). He noted that this was the third symposium organized by DIW and the U.S. National Academies to discuss issues of mutual interest in innovation and technology.

He said that both U.S. President Barack Obama and German Chancellor Angela Merkel had noted the importance of innovation as a tool for economic development. President Obama in his 2011 State of the Union Message said that innovation drives the United States' free enterprise system and creates tomorrow's jobs. In Germany, the Angela Merkel government had committed to spending 10 percent of GDP on research and education by 2015.

"That commitment," Dr. Wagner said "has been moved further into the 21st century in order to create sustainable economic growth, for which innovation policies play a critical role. Through clusters of creation by entrepreneurs and the development of creative ideas, innovation encourages the identification of solutions to current social and environment challenges."

INNOVATION AS MULTIDIMENSIONAL

Dr. Wagner said that innovation policy is by its nature multidimensional, reaching into education, finance, and employment, as well as science and technology. Effective innovation policy must take all these sectors into account, understand their consequences, and be based on knowledge and reliable data. However, he added, it is too simple to say that the innovation economy arises solely from areas of knowledge and policy. An innovation culture depends also on the wealth of people, their openness to new ideas, and their willingness to take risks. Only an open-minded and tolerant society can support sufficient innovative talent to allow the economy to grow rapidly.

He described DIW Berlin as "one of the leading economic research organizations," playing a vital role in developing Germany's innovation culture

through policy recommendations, regular reports, and evaluation exercises. A major focus of the institute is the socio-economic study of individual openness, risk aversion, and entrepreneurial behavior. Such studies, he said, provide insights that strengthen its recommendations to policy makers. He highlighted the recent finding of Alexander Kritikos, DIW's research director, that the most successful entrepreneurs are those with a moderate level of risk aversion.[1] Entrepreneurs who are too risk averse, Dr. Kritikos found, have a higher likelihood of failure; those who are "too risk-loving" likewise show a high incidence of failure. Achieving a "moderate level" of risk, he concluded, should be a key goal of policy makers as they shape innovation policy and subsidies.

Based on the "impressive line-up of speakers both from Germany and the United States," Dr. Wagner predicted that the symposium would help identify best practices in stimulating innovation in key industries, as well as in suggesting areas where the two nations can cooperate in the future. The first day would include topics of general interest, he said, followed by the second day's discussion of specific sectors, such as finance, CO_2 reduction, electric vehicles, the biomedical industry, and solar energy.

He thanked the major sponsors of the symposium, including the German Federal Ministry of Education and Research, GMBR and UFS Universal and Management Services, and the organizers of the symposium, including the staffs of DIW Berlin and the U.S. National Academies. He thanks also the German Embassy of the United States and Engelbert Beyer of the Federal Ministry of Education and Research (BMBF); Alan Wolff, the chair of the National Academies' Committee on Comparative National Innovation Policies, and Charles Wessner, program director of the National Academies' Board on Science, Technology, and Economic Policy (STEP) and his staff; and David Audretsch of Indiana University, a symposium speaker and head of CGRW's advisory board.

Alan Wm. Wolff
Dewey & LeBoeuf LLP
and
Chair, U.S. National Academies Committee
on Comparative National Innovation Policies

Ambassador Wolff joined Dr. Wagner in welcoming the participants to the symposium, noting in particular the presence of their Excellencies State Secretary Georg Schütte, Minister of State Werner Hoyer, and U.S. Ambassador to Germany Philip Murphy. He commented that the DIW Berlin and the U.S.

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[1]Marco Caliendo and Alexander Kritikos, "Searching for the entrepreneurial personality: New evidence and avenues for further research," *Journal of Economic Psychology,* 33(2):319-324, April 2012.

National Academies were well-matched partners for this review of national innovation policies, and recalled a successful preliminary U.S.-German meeting in Washington the preceding November.[2] He greeted the many distinguished guests and speakers on innovation policy, and noted that the current study had already held similar gatherings in India, Finland, Belgium, Taiwan, Japan, Poland, and China. "In fact, there is not a country disinterested in innovation policy," he said. "They are all working hard to capture value in the 21st century."

He began by agreeing with Dr. Wagner that innovation policy is a top priority for both the United States and Germany, noting that much of President Obama's State of the Union message in January 2011 was devoted to innovation policy, and included the assertion that innovation is a key to the future for U.S. competitiveness and growth. "That view marked a departure from every president's statements in the past," he said. He also agree with Chancellor Merkel's observation that with technology and innovation come opportunities that help "shore up the world's economy and address pressing global challenges in health and the environment."

Mr. Wolff briefly explained the role of the U.S. National Academy of Sciences in addressing the topic of innovation policy. The Academy's mandate is to provide the most objective scientific advice available to the U.S. Congress and to the executive branch of government on pressing issues in science-related areas, such as health, education, climate change, the environment, security, and, more recently, innovation. The STEP Board had undertaken "ground-breaking work" on innovation policy beginning more than a decade ago under the leadership of Gordon Moore, co-founder and past chairman of Intel Corporation. "This work," he said, "has helped make the STEP Board a center of global excellence on innovation policy."

The STEP Board in recent years has been led by Lawrence Summers, subsequently head of President Obama's National Economic Council, and Prof. Dale Jorgenson of Harvard University. Prof. Jorgenson's own research had demonstrated that information technology and other semiconductor-based technologies have stepped up the rate of economic growth in the United States by 0.5 percent, following a point of inflection in the 1990s.[3] Giving further support to this result was the conclusion of the World Bank that ICT contributes some 2 to 3 percent of GDP in the developing countries. [4] "So what we're

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[2]The National Academies STEP Board and the German Institute for Economic Research (DIW) in Cooperation with the Embassy of the Federal Republic of Germany convened on November 1, 2010, a symposium in Washington, DC, entitled, "Meeting Global Challenges: U.S.-German Innovation Policy."

[3]Dale Jorgenson et al., *Productivity: Information Technology and the American Growth Resurgence*, Cambridge MA: MIT Press, 2005.

[4]Christine Zhen-Wei Qiang, *Contribution of Information and Communication Technologies to Growth*, Washington, DC: The World Bank, 2004.

discussing today," said Mr. Wolff, "is of global significance. It's not just for Germany or the United States."

INSIGHTS INTO BEST PRACTICES AROUND THE WORLD

One distinguishing feature of the work of STEP, Mr. Wolff continued, is that "we pay attention to what the rest of the world is doing." This, he said, is because the policies of others "shape the environment in which we cooperate and compete, and because we firmly believe that we have things to learn from others." indeed, he said, the premise of the meeting was that the participating countries "can help each other with insights into what works and doesn't, and what are best practices."

The STEP Board is unusual in its long-term commitment to understand how U.S. trading partners and competitors encourage the development and retention of new industries. The Academies also review the conditions that have brought success domestically, such as the support of science and research parks and the intelligent funding of small, high-technology businesses. A particular focus has been the role of how innovative small companies can contribute to economic growth if they are adequately funded.

Mr. Wolff suggested that some people might question why U.S. experts and officials would be interested in German innovation policy. He said that the answer should be clear from a glance at Germany's impressive economic growth, its ability to sustain a high level of exports, and its high level and quality of employment—all despite high wages and a complex regulatory environment. He added that the German economy continues to export successfully around the world, not the least to China, which whom its trade is almost balanced.

At this stage of the STEP inquiry, he said, the Board had gained insights into the value of federally supported, basic research and the necessity for timely seed funding, whether provided by federal, state, or private programs. Increasingly, the board has focused on the interactions between government, the private sector, and universities; it had also discussed the incentives and new institutions needed to transform the results of research into products of value to the commercial market. While it had gained an understanding of the importance of venture capital in the U.S. innovation system, the group had also come to understand some of its limitations, which had become more evident during the current time of economic stress.

THE IMPORTANCE OF LOCAL VALUES FOR ENTREPRENEURISM

What was often left out of discussions, Mr. Wolff said, was the importance of customs, values, and laws that either encourage or dampen the entrepreneurial spirit. For example, bankruptcy laws in the U.S. enable entrepreneurs to take risks. When entrepreneurs fail, as some must inevitably do,

these laws permit prompt recovery and reallocation of human capital. Because of this and similar advantages of the United States' open and competitive market, the United States is rightly known for its entrepreneurial spirit, "perhaps the most unfettered of any on the planet."

As an example, he noted the case of Bethlehem, Pennsylvania, part of the "rust belt" that had long represented the "old economy" of steel manufacture. When the steel industry collapsed, Bethlehem collapsed with it—until it began to renew itself as a manufacturer of advanced medical equipment. Similarly, the state of Maine once relied on large textile centers in Lewiston, Augusta, Brunswick and elsewhere; when textiles moved south in the mid-20th century, textile workers lost their jobs—until they were retrained to work for the semiconductor firms that became the state's largest employer several decades later.

Mr. Wolff noted that many of the nation's broader deficiencies are familiar, such as secondary education in science and mathematics and the nation's physical infrastructure. "When we see places like Berlin, we see that we could do a little more," he said. "And when we go to Beijing and Shanghai, we know we have to do a *lot* more." The nation has also identified key priority areas for progress: curing disease; providing clean energy, for the sake of both the environment and national security; transportation; harnessing further advances in ICT; accelerated research on new materials; sustained investments in nanotechnology. "And we understand that we need to have supportive international and investment policies, including especially better protection of intellectual property, which is a major challenge in some areas."

TRANSFORMING INNOVATION INTO JOBS

Beyond these particulars, however, he emphasized a single major gap in knowledge for both the United States and Germany: "the right formula for transforming the benefits of innovation into high-quality jobs in large quantities." This, he said, was the "key concern of the U.S. government." He added, "It is not spinning straw into gold that's the challenge; our inputs are better than straw. The challenge is to rediscover the alchemy of moving from innovation to strong domestic employment in an era of globalization."

Mr. Wolff reiterated that Germany and the United States had much to learn from one another, and he proposed that "a regular exchange of information other going forward would be extraordinarily valuable." He said that the United States would be interested in learning more about German ideas on fostering innovation, "from the first spark of invention through to the challenges of commercialization, manufacture, and export. We also look forward to exploring prospects of future collaboration among U.S. and German research institutions, universities, businesses, and government agencies."

He emphasized the potential value of cooperation—even when progress seems hopeless. He said he had spent much of his career working with the semiconductor industry, and recalled "the challenge of Japan" in the 1980s.

Japan was then totally closed to competition, he said, and today "it is fully open. There is actually collaboration." The United States created the industry-government partnership SEMATECH at that time, at first confined to U.S. membership, and today the group is international; it had evolved from joint government-industry support to almost entirely private support, and membership today is open to firms worldwide, including its Japanese, Korean, and Chinese members.

"I have not entered a day of any of our symposiums with a stronger feeling of how much we can gain from an exchange," Mr. Wolff concluded. He again thanked Gert Wagner, chair of DIW, and his colleagues for hosting the symposium, and also Klaus Zimmerman, David Audretsch, and other organizers "for their vision in encouraging this series of cooperative meetings." He singled out for thanks Jens Schmidt-Ehmcke of the DIW "without whose efforts this symposium would not be taking place." He closed by introducing the next two speakers, Georg Schütte, State Secretary for Education and Research, and Philip Murphy, U.S. Ambassador to Germany, and praised "their commitment to better understanding of U.S. and German innovation policy and enhanced cooperation between our two countries."

Opening Remarks for Germany

Georg Schütte
State Secretary for Education and Research

Secretary Schütte welcomed his American colleagues and guests, and commented on the "wonderful event" held several months earlier at the American Embassy in Berlin. That event, attended by Charles Wessner from the U.S. National Academies and organized by Ambassador Murphy, served as preparation for the current symposium, "an intensive dialogue on the best paths for research policy, technology and innovation policy."

The current symposium, he said, sends important signals in two ways. The first was a common basic conviction shared by the United States and Germany: the belief that science, research, and innovation are central in the search for solutions to the major challenges of our time, including climate and environmental protection, improved health care, safety issues, and economic prosperity. Despite the need for budgetary restraint in both countries, both the administration of President Obama and the federal government in Germany had committed themselves to investment in research and development and affirmed the need to assign them higher priority.

The United States and Germany have cooperated closely for decades in the fields of science and technology, Secretary Schütte said, as the technological capabilities of two countries have grown. At the same time, both are facing great challenges. An appropriate response, he said, is for both sides to search together for ways to make efficient use of their resources of talent and capital, and to maintain the open exchange the two nations have enjoyed as long-time friends.

LEARNING FROM EACH OTHER

He offered three theses as a starting point for the symposium. The first was that the United States and Germany can learn from one another only when they understand their differences. They differ in fundamental ways, for example, in technological performance and competitive ability. In the past two decades, the United States had been at the forefront of global technological change, with high technology and new business models driving U.S. competitiveness. "In almost all types of advanced technology, it is American research centers and enterprises that are leading." At the same time, he said, the United States is

challenged to maintain this leadership as it recovers from the economic crisis and faces new competitive pressures from Southeast Asia.

In comparison, Germany directs a similar proportion of its GNP to research and development, ranging from 2.5 to 2.8 per cent, but this support is apportioned differently than in the United States. Funding is directed predominantly to traditional industries—automotive, chemicals, machinery—and serves to integrate newer technologies into these industries, to develop and integrate these areas into system products, and to develop high technology in a step-by-step manner. As one consequence, Germany is weak in the ICT sector, but strong in the automotive sector. Germany barely has any profitable Internet platforms but is developing the Internet of "things," the cyber-physical systems. Germany is a major software producer not as much for consumers as for systems technology. Germany is strong as well in production technology, he said. The country's role could be described as that of "world supplier and equipper."

CONTRASTING THE GERMAN AND U.S. INNOVATION SYSTEMS

His second thesis was that these technological specializations are mirrored in the countries' different innovation systems. The U.S. success with cutting-edge technologies is closely linked to several factors, beginning with the leadership of major research universities. A second factor is entrepreneurial spirit, which leads to success in new business models. A third factor for success has been the United States' ability to attract the best talent from around the world. Yet another strength, he said, are its highly efficient capital markets, particularly the availability of venture capital and risk capital. Finally, technological success is supported by government investments in R&D, which is "markedly higher than in Germany and Japan." These factors combined, he said, to create opportunities for disruptive innovations that are "significantly greater than in Germany and Europe."

In Germany, Secretary Schütte said, assets include the steady strengthening of the small and medium-sized enterprises known as the "hidden champions." These SMEs specialize in certain niches, and become world leaders in very specific technologies, notably through the highest levels of quality. For these companies, the economic crisis was an opportunity to re-examine and adjust their portfolios, procedures, and structures.

More generally, German companies benefit from the close integration of large and small companies, close ties with public research organizations, and links with the Fraunhofer Society, which works at the interface between publicly funded research and corporate research institutes. He noted the high efficiency of German universities and German research centers, not so much in individual projects but in their breadth, along with a long-standing debate regarding whether this model is sustainable.

"Some analysts tell us," Secretary Schütte said, "that we're now riding in the dining car of the world economy and eating for breakfast the opportunities that the market is currently offering. These include a boom of supply and demand for new technologies from South Asia and Southeast Asia, which in some ways are complementary to German strengths. But when this boom is over, the analysts say, we will have to pay the price." He added that no one could tell whether this was "a typical case of German self-doubt, or whether it is the correct view."

At present, he said, Germany is seeing high demand for energy and environmental technology products and, more generally, for systems technologies. Economic growth is above long-term trends and many industries experience labor and skills shortages. This brings a new set of issues for the German innovation system: how can the country use its finite human and capital resources in the most flexible and productive ways? In the face of limited resources, how can Germany continue to create value and increase the income of the citizens? A new challenge is to integrate into the labor market talents that remain on the periphery because they come from different cultural backgrounds.

SIMILARITIES AND COMPLEMENTARITIES

His third thesis, he said, drew not from differences between the two countries but from similarities. Germany and the United States have similar resources in research, technology, and innovation policy. One such resource is an ambitious and comprehensive innovation strategy. A common feature of both strategies is addressing the need to better translate available funding into innovations. The basis for innovation in both countries, according to analysts, is an efficient scientific system. Similarly, both countries cooperate in addressing "grand challenges," including energy research, energy supply, mobility, and electric mobility. Both search for solutions that span the political field, including cross-application technologies. The U.S. supports the Nanotechnology Initiative (NNI); Germany has an Action Plan for Nanotechnology. Both use similar orientations and similar instruments. Both countries work to unleash entrepreneurial spirit, support young companies, and broaden and improve the framework for technology-oriented businesses. Both are struggling to respond to the challenges posed by Southeast Asian competitors. For each, education is the foundation for present and future policies. "But with all this in common," he said, "we should not forget that our two institutional frameworks are quite different," including the customs and even the rhetoric used to describe frameworks and challenges.

KEY QUESTIONS

Secretary Schütte concluded by offering a summary of some of the questions that drive Germany. First, it seems sensible to compare "best practice"

examples for various specific fields. What solutions and which models work, for example, in energy policy and energy research? What can the countries learn from one another in policy design?

Second, he said, the countries face similar unresolved challenges on many issues, including patenting, network neutrality, electro-mobility, and bio-medicine. "It seems meaningful to ask: What is the state of affairs? How can we compare them? What can we learn from each other?"

Finally, he asked, "where can we succeed through increased cooperation to tap into common potentials?" For example, he suggested, both countries share an interest in using renewable energy as efficiently as possible. In such areas, there may be not only common technological interests, but also common political challenges and goals. "If we share a consensus that education, research, and development are so important that they should take precedence over other policy areas, how can we convince our political representatives? How can we convince the public that it is important, despite the need for fiscal restraint, to spend more money in this area than in other areas?"

Secretary Schütte recalled President Obama's State of the Union address, in which he said "we need to out-innovate, out-educate, and out-build the rest of the world." If that is correct, he said, it will require individual countries to find parts of the answer. But it will also require cooperation among those nations to find the full set of answers and implement them together. "It's this combination of competition and cooperation that will lead us forward," he concluded, urging participants to keep this in mind throughout the symposium: "Where can we cooperate? How can we cooperate in such a way that competition will help us move forward?"

Opening Remarks for the United States

The Honorable Philip Murphy
U.S. Ambassador to Germany

Ambassador Murphy thanked the "U.S. team" for attending, and emphasized "how meaningful it is to our mission to have you here—not just in Berlin but throughout the country." He recalled the planning dinner in Berlin with some of the participants several weeks earlier. "I learned a lot that night," he said, "and it became clear that Germany and the United States and their leaders in the field of innovation have a long history of working together." He noted also that the two countries had some different approaches to the subject. "Those different perspectives, however, I believe are opportunities to learn from one another and to strengthen our relationship." He called the symposium "a perfect example of how we turn these opportunities into tangible results."

He noted that humanity had depended on technology-based innovation for its economic progress for centuries, and that this dependence at the start of the 21st century was more pronounced than ever. The world is now more complex, interconnected, and resource-constrained, he said, and in the face of global challenges such as climate change, increasing energy demands, dwindling water resources, food insecurity, and persistent diseases "we will need to harness technology in new ways to ensure economic growth and social development. Now perhaps more than at any time in history we need the tools of science and technology to build that sustainable future that people around the world want and indeed demand. 20th century technology is no longer sufficient to deliver 21st-century solutions."

The goal of the symposium, he said, was to identify concrete areas where Germany and the United States can share best practices on such matters as funding initiatives, intellectual property rights, peer review, scientific exchange, public-private partnerships, and the role of NGOs. Over the past six-and-a-half decades, he said, the transatlantic relationship in science, technology, and innovation had been a success. Large, medium, and small companies from both countries had made considerable investments on both sides of the Atlantic—"investments that develop and implement new technologies and create jobs."

EXAMPLES OF U.S.-GERMAN COLLABORATION

Mr. Murphy offered two recent examples. The first was "the world's largest onshore wind energy park," located on former cotton farmland in Texas. The Rock Hill Wind Farm is owned and operated by the German energy company E.ON, which has installed 600 wind turbines capable of generating over 780 Mw of electricity. The second was the decision of the world's second-largest photovoltaics manufacturer, First Solar, a U.S. company, to site its main manufacturing plant in Frankfurt on der Oder.[5] "Both E.ON and First Solar are shining examples of how innovation can bring new jobs and investments to areas that need them," he said.

Both countries, he continued, have a long history of robust, bilateral scientific and technological investment. The United States and Germany have similar targets of investing more than 3 percent of GDP in public and private research and development. These investments in basic and applied research create incentives for private innovation. In both countries, the universities, federal labs, and industrial laboratories conduct research that leads to breakthrough products and new companies. German and American counterparts work closely together to foster research and innovation. The Fraunhofer Institutes, for example, have seven research centers in the United States, and the Max Planck Society now has a Center for Bio-Imaging in Tampa, Florida. There are more than 50 bilateral cooperation agreements between individual institutions on topics ranging from earth sciences to energy physics to public health.

As strong and productive as this relationship has been, he said, it is desirable to reinforce and expand both long-standing and more recent connections. The relationship was given a more formal structure through a science and technology agreement signed by the two countries on February 10, 2010, describing an administrative framework for cooperation. The objective is to continue to identify and intensify relations in education and research, to coordinate joint research teams, and to interlink shared national priorities in science policy to the benefit of both sides.

Mr. Murphy pointed to renewable energy as one area where the countries already work together. The United States formally joined the International Renewable Energy Agency, or RENA, on March 4, 2011. In Germany the Bonn Innovation Center for Renewable Energy also opened in 2011, where the United States looks forward to partnering in the development of clean technologies. The U.S. National Renewable Energy Laboratory (NREL) in Colorado has been collaborating on solar research with three institutes of the Helmholtz Association since 2008. The partners are seeking to broaden the

[5]Frankfurt on der Oder, or Frankfurt (Oder), is smaller than Frankfurt am Main and located in the former East Germany on the Oder River, which forms the German-Polish border.

range of their research through a new MOU focusing on solar photovoltaic materials and systems, including solar fuels and concentrated solar power (CSP), as well as performance and reliability.

"I am often asked what I predict for the future of German-American relations," he said, "and how our two countries can impact the world in development and stability. As the world's pre-eminent manufacturing and innovation centers, Germany and the United States can not only set an example by growing their own economies; they can also advance technological know-how and innovative developments that grow the global economy and serve the greater international community."

Mr. Murphy concluded with "an important lesson" relevant to both the public and private sectors. "It is far better to compete by innovating, leading, and collaborating," he said, "than by standing still. This symposium is an important platform to discuss how we best take advantage of our innovative capabilities both to compete and to collaborate."

Keynote Address

John Fernandez
Assistant Secretary
U.S. Economic Development Administration

Secretary Fernandez thanked Chairman Wagner, President Zimmerman, and U.S. National Academies for organizing "this prestigious event," as well as Ambassador Murphy and State Secretary Schütte for their leadership in strengthening German-U.S. commercial relationships. He described the symposium as "an excellent opportunity to collaborate, show best practices, and discuss some of the challenges" of strengthening innovation. "I look forward to learning from you and working with you," he said, "as we seek to brighten both our nations and futures."

He said that he would focus his remarks on "how the United States under President Obama's leadership is working to restore the strength of the innovators, and to keep us competitive in the 21st-century global economy." He began with several major global challenges. The first was the structural changes in the world economy, which has brought new competition from all parts of the globe. The second is the ongoing recession that has affected the global economy—a recession "caused in part by poor financial regulatory decisions, a recession that has impacted world trade and pointed to the widening imbalances between developed nations and the rest of the world." The third was the need to "face the impact of our unsustainable dependence on oil, a dependence that threatens the global economy by driving gas and energy prices higher."

As serious as these challenges are, Mr. Fernandez continued, there is unprecedented opportunity characterized by innovation, research and development, exports, and emerging sectors, such as clean-tech and low-carbon industries. These are opportunities "that promise an economy that works for everyone, regardless of where they live in the world." As a candidate, President Obama said to the people of Berlin in July 2008, "While the 20th century taught us that we share a common destiny, the 21st has revealed a world more intertwined than any time in human history."

SUSTAINING A FLOW OF NEW IDEAS

Those involved in development issues have increasingly recognized the critical role played by innovation in assuring success in the global market place, he continued. In the United States, the economy depends heavily on a continuous and open flow of new technologies and new ideas. Sustaining and encouraging that inherent capacity is a top priority in attempting to maintain America's economic leadership. This emphasis, he said, was reflected by the President's 2011 State of the Union speech. "I don't think we've ever heard a State of the Union address so focused on innovation and our country's commitment to support it," he said.

This commitment begins with several building blocks, Mr. Fernandez said: people, ideas, and networks. First, innovation is possible only through the actions of a skilled and talented work force, and strengthening this work force is the beginning point of the administration's strategy. The second building block is continued investment in basic research to accelerate the knowledge breakthroughs that mark the beginning of the innovation cycle. The President proposed doubling the nation's investments in R&D, and eventually increasing them to the level of 3 percent of GDP. Third, an innovation economy depends on modern infrastructural networks, including the smart grid, next generation air traffic control, new wireless communications systems, and other systems that move people and ideas with speed and efficiency.

REMOVING BARRIERS TO INNOVATION

While investing in these building blocks, he said, the Administration is also working to remove barriers to innovation. It is attempting to improve the patent system, both to increase the quality and quantity of patents and to reduce delays in processing. The Administration is also reviewing federal regulations to assure that rules facilitate rather than impede competition and innovation. To help ensure an environment in which small and large business can thrive, the President called for major tax reforms, including making permanent the research and development tax credit and bringing the corporate tax structure more closely in line with many of OECD counterparts.

Finally, the strategy supports entrepreneurs through initiatives like Startup America, launched by the White House in January 2011 to promote entrepreneurship across the country. Startup America is investing $2 billion to help entrepreneurs by lowering barriers to high-potential, fast-growing small companies, especially in high-tech fields such as clean energy, nanotechnology, biotechnology, and advanced manufacturing.

The Obama administration, Mr. Fernandez said, has recognized that the strength of the national economy depends on the strength of its regional components. In fundamental ways, the President's innovation strategy depends on the cities, counties, and states where innovation actually occurs. A basic decision by this Administration has been to press for greater coordination among

the federal agencies charged with reaching out to the regions, and ensuring that the regions have the incentives, support, and knowledge they need. Primary mechanisms for this outreach are innovation clusters where universities, businesses, research institutes, foundations, political organizations, and others intersect as partners to work toward common development goals. This is a significant departure from earlier economic development policies that often promoted a "race to the bottom" in which cities, counties, and states undercut each other to attract short-term growth.

The Task Force on Advancing Regional Innovation Clusters (TARIC) is a collaboration of federal agencies that seek to advance the growth of regional innovation clusters in the United States. While innovation clusters have existed for decades, beginning with the North Carolina's Research Triangle Park in the 1950s, only recently does the federal government have a strategy to promote and align investments that support these clusters.

PROGRAMS TO JUMP-START GROWTH

In addition, in May 2011, the Economic Development Administration of the Department of Commerce (EDA) launched an initiative called the Jobs and Innovation Accelerator Challenge to jump-start innovation-fueled growth. The Jobs Accelerator is a joint effort of 16 federal agencies designed to promote growth through public-private partnerships in at least 20 pilot regions that demonstrate high-growth potential. Each of these accelerator challenge investments will serve as a catalyst to leverage private capital in the regions from foundations, corporations, financial institutions, and other private partners. This competition builds on the success of an earlier pilot project, the Energy Regional Innovation Cluster (ERIC), launched in 2010. That initiative provides about $130 million from seven federal agencies to create a regional research center, develop new building efficiency technologies, and cluster the work of local partners to implement these technologies in local businesses and buildings. Today, ERIC, which was won by the Greater Philadelphia Innovation Cluster consortium, is investing resources to commercialize research, launch new small businesses, and connect education and work force training strategies.

These efforts are coupled with high-risk, high-reward policy tools, such as the i6 Challenges proof-of-concept competition that is designed to help move innovative ideas from the lab to the market place. The EDA is also promoting a Regional Innovation Acceleration Network to connect venture development organizations within America's regions to promote best practices.

Mr. Fernandez lauded President Obama for his "understanding the power of innovation and its importance to the future of our national competitiveness." At the heart of competitiveness, he said, was the simple truth that "when you expand opportunity to more people, it creates more opportunity for everyone." That work "is not yet done," he said; substantial parts of the United States have not participated in the high-growth innovation economy. There are many cities and towns that were one thriving but are now suffering.

Our national objective is to ensure that new opportunities "are not just for the biggest cities, or for people with advanced degrees or good connections. Everyone needs to have a stake in this innovation-fueled economy."

He concluded by saying that "what is true for communities within the United States is also true for relationships between countries." The benefits of global economic growth over the past few decades have not accrued equally to everyone, he said, "but we're confident that the President's strategy for American innovation, as well as other forms of engagement, will help broaden opportunities for those who have not yet had them."

Panel I

Current Trends in Innovation Policy

Moderator:
Jens Schmidt-Ehmcke
German Institute for Economic Research (DIW Berlin)

Dr. Schmidt-Ehmcke said that both President Barack Obama and Chancellor Angela Merkel had emphasized the importance of innovation in encouraging economic development, fostering growth, and creating jobs. The aim this panel, he said, is provide an overview of each nation's policy initiatives to accelerate these activities. "We hope to learn from each other's programs, compare tools, and discuss best practices. Our innovation systems are different, as are the roles of the governments. However, both nations share similar goals and challenges." For example, both aim at creating the leading innovation systems of the world, he said, and both understand the power of innovation and technology to address societal problems. Both nations are also attempting to provide sufficient financial resources for the innovation ecosystem, and both find themselves facing intense competitive pressure in now-global markets, especially from Asian countries. He expressed confidence that this panel and symposium would provide the opportunity to learn more about valuable strategies to address these common goals.

U.S. INNOVATION POLICY: NEW INITIATIVES

Ginger Lew
Senior Counselor
White House National Economic Council

Ms. Lew noted that she and the following two speakers had all been entrepreneurs, and each had worked as a member of venture capital funds that invested in young companies. "It is from that perspective that we view innovation," she said, "and its important role in our economy." With that background, she continued, is it is natural to see innovation as a key to economic development from the perspective of the National Economic Council as well.

She expressed gratification that the Obama administration had made innovation one of its top priorities for the last two-and-a-half years. Typical of its approach, she said, was the new initiative Startup America, which is linked to the main innovation agenda. This initiative supports not only basic R&D activities, but also the activities that keep the economy competitive and vibrant, including change, risk taking, and new opportunities, "all of which are at the core of the entrepreneur's DNA."

Startup America for High-growth Entrepreneurship

Startup America, Ms. Lew said, is a White House-led initiative to "celebrate, inspire, and accelerate high-growth entrepreneurship across the country." Startup businesses play a key role in job creation in the United States, she said, with small firms creating more than 40 million net new jobs in the past 15 years, or two out of every three new jobs. "We cannot predict what technologies or innovations are going to completely change the game or our lifestyle," she said. "But we do know that when these bursts of innovation happen, it is very likely that an entrepreneur is responsible. These are the people who are willing to mortgage their homes, work 100-hour weeks, and throw caution to the winds in pursuit of an idea." Some entrepreneurs go on to build large multinational companies, she said; most do not. They all contribute to a vibrant and innovative economy. "Consider the fact that small businesses in America generate 15 times more patents per dollar than large firms," she went on. "Small businesses employ more scientists and more engineers than America's universities and federal labs combined."

When the White House launched the Startup America initiative in January 2011, the President challenged leaders of both government and the private sector to accelerate the success and economic contributions of America's entrepreneurs. He asked them to do so in four ways: mentoring, increasing access to capital, reducing regulatory burdens, and accelerating the commercialization of federally funded research. She said that all four were part of her portfolio at the White House.

From the government side, Ms. Lew noted, the Obama Administration had designed this program with "a relatively light touch." She gave the following description of the program's four pillars:

- Mentorship: We are looking to lead by example. When entrepreneurs are asked what they need help with, their first answer is not necessarily money; instead, they want access to successful CEOs to help coach them through their growth pains. The DoE and SBA have agreed to recruit 200 successful serial entrepreneurs who will mentor 100 companies that receive DoE funds to bring promising technology products to market.

- Access to capital: The administration had announced two new funds. The Impact Fund makes capital available to investment managers who invest in companies in underserved regions or industries considered a national priority. Seventy percent of all U.S. venture capital goes to three regions: Silicon Valley, Boston, and New York. Other regions also have vibrant entrepreneurial communities—yet lack the capital and resources that could allow them to blossom. The other fund is the $1 billion Innovation Fund, which will make capital available to investment managers who invest in very early-stage companies. The goal is to help companies that have found promising technologies at research facilities to develop those technologies beyond the proof of concept stage.

- Regulatory barriers: Every country has regulations, and business people often contend that there are too many. In the case of startup companies, my office decided to ask the businesses themselves to name their top regulatory hurdles. We engaged in energetic discussions with entrepreneurs in Silicon Valley, Minneapolis, and Atlanta. We also set up an online platform to solicit suggestions. This exercise confirmed the value of a bottom-up solicitation of feedback, suggestions, and input. We truly believe that good ideas are to be found in the cities and towns where most of our citizens live and do business. We will take all 200 suggestions we received and choose the top 10 to eliminate or streamline.

- Accelerating commercialization of federally funded research: While not all research should be commercialized, we want to move more of our ideas from the laboratory bench to the marketplace. We're also focused on getting the best return from the $148 billion the United States invests annually in research. Recently the DoE launched a competition called America's Next Top Energy Innovator. The goal is to cut up-front patenting/licensing costs and challenge entrepreneurs to commercialize more technology developed in our national laboratories.

Clusters to Foster Public-private Partnerships

A week before the Berlin symposium, Ms. Lew said, the Administration announced the Jobs and Innovation Accelerator Challenge, a multi-agency competition to support the advancement of 20 high-growth, regional industry clusters. She said that these clusters are designed to foster coordination between the private and public sectors to catalyze the unique

strengths of various regions, and encourages federally funded research centers and their regional partners to participate.[6]

She returned to the importance of Start-Up America, which two weeks earlier had announced commitments from more than 15 companies and organizations. Each committed to delivering "strategic and substantive resources" to accelerate entrepreneurs who were starting and scaling businesses.[7] These new private sector partnerships delivered more than $400 million in value to U.S. entrepreneurs, she said, building on the 20-plus companies already enlisted in the Startup America partnership, including Intel, IBM, American Express, Cisco, Ernst & Young, First Data, Google, HP, Intuit, Linked-In, and Microsoft.

The partnership also included members from the non-for-profit and foundation sectors, including the Blackstone Foundation, which had recently announced the Master Entrepreneurship Program. This five-year effort was launched with four North Carolina universities.

Ms. Lew said that the partnership has reached out in many directions to empower entrepreneurs. To expand its mentoring function, for example, the National Center for Women and Information Technology had agreed to help coach women entrepreneurs; Palindrome Advisors[8] had committed to connecting 1,000 minority entrepreneurs with top industry advisors.

In addition, the Angel Capital Association and the Angel Resource Institute announced that they would double the number of high-caliber investors affiliated with angel groups across the country, increasing annual investments by more than $1 billion. Qualifying Startup America member companies would be matched with angel investor mentors to help grow their businesses. Finally, the National Venture Capital Association intended to provide access to its 400+ venture capital firms, its 4,000-plus investors, and thousands of venture–backed companies' CEOs.

"This public-private partnership," Ms. Lew concluded, "together with the enthusiastic support of the private and foundation sectors, has the potential to be game-changing for American entrepreneurs. By leveraging limited

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[6]Winners of the 20 awards were announced by the Department of Commerce in September 2011 for proposals in advanced manufacturing, information technology, aerospace, clean technology, and other fields. Each winner receives an average of $1.8 million, contributing an additional $13 million in matching funds. Grantees estimate that their clusters will create more than 4,800 jobs and 300 new businesses, as well as retain another 2,400 jobs and train some 4,000 workers.

[7]According to its website, the Startup America Partnership is a private organization working to help young companies succeed in order to accelerate job growth in America. The partnership has three main goals: (1) provide valuable resources and connections to help young companies grow; (2) support regional startup ecosystems throughout the country; (3) recognize startups as the drivers of our economy and their founders as American heroes. Its CEO is Scott Case, founding CTO of Priceline, and the Chairman is Steve Case (no relation), philanthropist and founder of AOL.

[8]Palindrome Advisors is a nonprofit organization based in San Francisco that helps business executives "give back" to startup organizations through mentoring, board service, volunteering, and tool-building. <*http://www.palindromeadvisors.org*>.

government resources with the dynamic energy of the private sector, we believe we can elevate America's entrepreneurs to the next level. We do this because we believe entrepreneurs are central to America's ability to compete and to prosper in the 21st century."

NEW INITIATIVES IN GERMAN INNOVATION POLICY

Dietmar Harhoff
Chairman
Commission of Experts for Research and Innovation

Dr. Harhoff said that he, too, had attended the "precursor of this event" in Washington, and had found it to be a "helpful exchange of views on science and innovation policy." He had spent much of his adult life in the United States, he said, so that he could confirm from personal knowledge Ms. Lew's description of the entrepreneurial spirit that often drives U.S. innovation. Ms. Lew had pointed to the story of Apple and its founder Steve Jobs as a model of transforming ideas into profitable products. In contrast to this success, he cited the counter-example of the MP3 player, which was invented in Germany. Despite its provenance, MP3 technology generated at its peak year only about $100 million in licensing revenues, "which I estimate is less than one-tenth per million of the value added of the overall industry."[9] This exemplified a key difference between the two countries, he said, which is that innovators in Germany have been far less successful than their American counterparts at maximizing the profitability of their inventions.

Results of an Independent Commission

He turned to the Commission of Experts for Research and Innovation (the German abbreviation is EFI, for Expertenkomission Forschung und Innovation). The EFI had commenced work in 2006 and by 2011 had completed four reports for Chancellor Merkel and the German government. Independent of government, the commission was free to pick its own topics. He praised the policy makers who created the commission for this "risky" strategy. "I have to hand it to them," he said. "But we have not disappointed their expectations. We do not seek to maximize pain or praise. We pick our topics because we think they are important to the long-term, sustainable welfare and growth of Germany." EFI commissions also supported some 15 in-depth studies per year.[10]

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[9]Per mil, a term rarely used in the United States but common in Germany and many other countries, signifies per thousand, or 0.1 percent. One-tenth of per mil would be only 0.01 percent.
[10]These are available at <*http://www.e-fi.de*>.

Results of new policies for innovation, he continued, may "take a long time to work their way through the system." Dr. Harhoff said that changes to the technology system that can make it "more equity friendly and venture capital friendly do not happen overnight, especially in Germany."[11]

The broader task of the commission is to "engage in interdisciplinary discourse related to innovation research." In particular, the EFI is asked to consult on scientific policy in three areas:

- Description and analysis of structures and trends and of the technological performance of the German research and innovation system.
- Analysis of central issues pertaining to the German research and innovation system.
- Development of policy options and recommendations leading to improvements of the German research and innovation system.

The commission's 2011 report was issued by six members with expertise in such fields as taxation, sociology, venture capital, economics, renewable energy, and innovation management. A subsequent report was then in the planning stages, the contract for support services was about to be renewed, and some members were being reappointed in order to continue a smooth system of operation.

Dr. Harhoff noted that all of the EFI reports comment on recent developments and new initiatives and discuss some core topics in greater depth. About half of each report consists of data, he added, because "we are academics, after all."

The 2011 report began with a look back at the impact of the financial and economic crisis. Despite the severity of the recession, the country had "bounced back nicely," thanks in part to the existing R&I infrastructure and by the investment by a public fund in several new technologies.

Support for Education—Even During a Recession

Despite the recession, the EFI supported continued spending on education, even in 2008. Some people were surprised at the commission's recommendation, he said, and the EFI coined the phrase "education is innovation policy" to make clear the purpose of its strategy. "We still have some serious challenges there, and major weaknesses."

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[11] As an example of a policy that may work against successful innovation in Germany, he described the case of the director of the Fraunhofer solar research institution in Freiburg, Prof. Dr. Joachim Luther. Forced to step down as director at age 65 by mandatory retirement rules, Prof. Luther was invited by the government of Singapore to plan and direct that country's new solar infrastructure, and his talents were lost to Germany.

The commission also focused on statistical measurement of innovation activities, using a technique he called community innovation service. Dr. Harhoff said that colleagues in the United States discussed the adoption of a similar technique, and urged them to do so. "This would be very welcome because then we could compare our activities in more depth."

The commission examined several other topics as well, including a new policy initiative for Germany called High-tech Strategy 2020, which laid out innovation goals for the coming decade. It also reviewed the European patent system, which it found high in quality but fragmented, which he called "the European disease."

Plusses and Minuses of Federalism

Among the core topics addressed by the commission was federalism, which has important consequences for innovation policy. The federal system, which he said was similar to that of the United States, had "some nice features and some not so nice." Federalism can be productive, he said, because it brings decision making down to where the information is. At the same time, he said, it can be hard to coordinate strategic themes in a federal structure.

Dr. Harhoff explained that a federalism reform in 2006 had caused particular problems. One new policy made it very hard the German states to cooperate with federal agencies on any matter related to educational planning. One result is that 18 tests are used in the 16 states to rate language skills. There is no agreement on which tests are best, because they have not been systematically compared. He said that an excellence initiative in universities was doing better, with good coordination between the federal and regional levels.

In addition, he said that while the United States had only one level of federalism, Germany had "two federalism problems"—one between federal and regional levels in Germany, and a second in regard to the European Union, which has its own innovation policies. "This brings even more of a need for coordination," he said.

Finally, Dr. Harhoff mentioned a discussion by EFI of "innovation without R&D," or design-based innovation. This level of innovation, he said, was difficult to measure because current metrics are based on the relationship between R&D and GDP. "It turns out that the more we look at this model, the more we see that it is not the best measure we could hope for."

He commented that President Obama had "proven to be a very good partner for people who think about innovation and science policies," and said he had experienced this commitment first-hand at a meeting in January 2011 at the U.S. State Department. "I was impressed by the intellectual leadership there," he said, "with the projects undertaken, and the attempts to bring innovation policy into development policy." He had also learned about Grand Challenges Canada,

where people from any nation can apply for funding for health care innovation research.[12] "What impressed me most," he said, "was the openness of some young, energetic people in North America to think about these issues, and the clear indication that innovation was at the top on their list of priorities."

Innovation Leadership at the Top

Dr. Harhoff said that meetings between the EFI and the chancellor and members of her government indicated that this openness was true for Germany as well. "Innovation must start at the top," he said. "In Germany, there is willingness to talk about it; I think that support for additional spending for R&I in Germany is in part due to our leaders being familiar with the issues in science and innovation."

He turned to Germany's High-tech Strategy 2020. The government had already encountered difficulties in gathering all the federal and state policy makers whose activities are relevant to innovation, and persuading them to communicate and coordinate their policies. In 2007 the previous government had started an initiative called the High-tech Strategy. The main element was to bring together not just the ministries related to economics, transportation, environment, and others in one forum; this had already been done with some success. The new element of the High-tech Strategy 2020 for Germany was "a very clear approach toward mission-oriented policies." This broke with the past in an important way. Fifteen or 20 years earlier, innovation policy often consisted simply of identifying "this little market failure or that one, and fine-tuning it here or there. We're coming now to an overarching view of the system, not just the externalities and market failures. It's about coordination, communication, and maybe even about strategies."

A major topic on his list was electromobility, which describes the systems that support the widespread use of electric vehicles, including design, systems integration, energy generation and distribution, and storage technologies. "In 2008," he said, "we were caught napping." In the 15 years preceding the financial crisis, German universities had undone 15 to 20 professorships in electrochemistry, which is the basis of battery technology. Germany had suddenly awakened, he said, and was trying to catch up to countries such as Korea, China, and Japan, which are best positioned in battery technology.

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[12]Grand Challenges Canada, according to its website, is a "unique and independent not-for-profit organization dedicated to improving the health of people in development countries through innovation."

A Venture Capital Bottleneck

Turning to venture capital, Dr. Harhoff praised Ms. Lew's "convincing speech on the virtues of entrepreneurship," and recommended that her words be carefully noted in Germany. "When you look at the usual statistics," he said, "we're not doing all that well in entrepreneurship." "It's not that entrepreneurship is deficient from our genes. We had a very entrepreneurial face after World War II, and of course the 19th century had booming entrepreneurship. The Siemens, the Krupps, other companies are still here."

The problem for entrepreneurship, he said, lay with some of its "boundary conditions," such as venture capital. This topic had been taken up recently, he said, including an "innovation dialogue" on April 7 with Chancellor Merkel and ministers. "Now VC is not everything," he said, "but several studies point to the fact that for Germany it is really the bottleneck right now."

Dr. Harhoff closed on a note of optimism with an example of how entrepreneurship was increasingly international—and how its benefits can be shared by international partners. A start-up from his own institution, Ludwig Maximilian University (LMU) in Munich, received private funding from the university incubator. The firm moved its business development to Silicon Valley, where it hired an Indian CEO who had been a vice-president of marketing at Google. It was profitable within two years; Motorola then completed a trade sale for a significant sum of money, and followed the sale by investing in R&D at the Munich location. "It's a complex example," he said, that had been criticized by some as "selling out German technology." But he concluded by urging his audience to hear a different message: that progress in a global marketplace is a function of cooperation and coordination.

POLICY INITIATIVES AT THE U.S. NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Phillip Singerman
Associate Director for Innovation and Industry Services
U.S. National Institute of Standards and Technology (NIST)

Dr. Singerman began by recalling an OECD symposium on innovation as long as 20 years previously, where he spoke about "the American job creation machine" and about seed funding at the federal and particularly the state and regional levels." He expressed gratitude to the organizers for another chance to participate in this topic, "not to lecture but to learn—about the innovative German manufacturing export engine. This is important to us in the United States," he said, "because our policy makers have finally recognized the important role manufacturing plays in an advanced, innovation-driven economy."

He noted several reasons for this. His personal view, he said, was that because manufacturing creates high-wage, high-quality jobs, it is a key

component of an export economy. "We simply cannot sustain an export-driven economy through financial services or a single aerospace company," he said. A third reason was the importance of the defense industrial base. "Electronic warfare is really the warfare of the 21st century," he said, "and with the erosion of an industrial base, we cannot manufacture the high-tech components necessary." A final reason, important for this symposium, he said, was the close connection between manufacturing and innovation. "As mentioned earlier," he said, "more than two-thirds of private-sector R&D in the United States is conducted by manufacturers. We have learned that R&D by itself is not enough, and it's not sustainable if there's no connection to the shop floor. We have seen frequently over the last 30 years that competitor nations first learn to do low-end commodity production and then work up the value chain to take over R&D capabilities. This is not a future that we can support."

Dr. Singerman noted that President Obama's fiscal 2012 budget was a very strong statement of support for physical sciences in the NSF, the DoE's Office of Science, and NIST. The total physical sciences budget exceeded $1 billion, an unprecedented level and a 17 percent increase over the previous budget.

In addition, he noted that the America COMPETES Act rebalanced the federal government's R&D portfolio "to meaningfully promote excellence in technology, engineering, and science." Reauthorized in 2010, this legislation recognized manufacturing as an important component of the innovation agenda. It called for the designation of a Committee on Technology under the National Science and Technology Council that would be responsible for planning and coordinating Federal programs and activities in advanced manufacturing research and development.

NIST's Role in Extension and Assistance to Industry

Dr. Singerman then turned to a discussion of NIST, which had been created more than a century earlier—as the National Bureau of Standards—to provide American industry with an intellectual infrastructure in measurement and standards that was necessary to compete with Great Britain and Germany. A century later, after the decline of the large industrial R&D labs, NIST had become "industry's national laboratory."

He observed that NIST's tradition of scientific excellence through a nationally funded set of research institutes is well known; not as well known is its work in extension and technical assistance to industry. This role was recognized in the America COMPETES Act, which upgraded the position of the NIST director to Undersecretary of Commerce for Standards and Technology, with responsibilities across the administration. Dr. Singerman said that four programs under his responsibility are focused on manufacturing.

The first is the Manufacturing Extension Partnership, a federal-state partnership with funding shared by the private sector. It coordinates more than 1,600 field representatives at non-profit and quasi-public organizations in all 50

states. This program was established 25 years ago, in response to the competitive challenge from Japan, and began by focusing on cost saving and lean manufacturing. It is now expanding its services to help small firms develop new products and new markets. The America COMPETES legislation also gave NIST new assignments to work on green technologies, on the workforce needs of manufacturers, and with the Economic Development Administration (EDA) on a loan guarantee program for innovation manufacturing technologies. Fortunately, he said, the need to grow the manufacturing base has bipartisan support, and the MEP program received nearly all the funding requested. This program, he added, is the nearest U.S. analog to the Fraunhofer Institutes, although more limited in scope and not as well funded.

The second NIST program was the Technology Innovation Program (TIP). This was originally the Advanced Technology Program, also created 25 years ago to focus on early-stage funding for high-risk, high-reward technologies. A portion of the program is being refocused to fund small and young manufacturing companies, supporting those that work with universities, federal labs, and industrial consortia.[13]

The third initiative is the new emphasis, led by Ms. Lew, to leverage the enormous annual investment of more than $50 billion a year in the mission-driven federal research institutions, such as those of the DoE, the NIH, and the DoD. NIST has several unique roles in transferring technologies from the federal labs. First, all regulations that govern the technology transfer have to be issued by NIST. Secondly, it is responsible for tracking and reporting on the performance of the federal agency laboratories. Third, NIST is the federal coordinator for the consortia of federal lab technology transfer offices. Fourth, it chairs the interagency working group on technology transfer. It carries out these responsibilities in partnership with sister agencies within the Department of Commerce, particularly EDA.

The fourth initiative was a pilot program for advanced manufacturing technology consortia. The objective is to stimulate the creation and to support the existence of industry-led consortia working collaboratively on pre-competitive manufacturing technologies. A model for this program is SEMATECH, created more than 20 years ago by the semiconductor industry and the DoD to strengthen manufacturing capabilities in the semiconductor industry. It was so successful that after four years industry decided to fund the

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[13]Independent evaluations by the National Research Council found ATP to be "an effective federal partnership program." See National Research Council, *The Advanced Technology Program: Assessing Outcomes,* Washington, DC: National Academy Press, 2001. The successor to the Advanced Technology Program, the Technology Innovation Program (TIP) at the National Institute for Standards and Technology "supports, promotes, and accelerates innovation in the United States through high-risk, high-reward research in areas of critical national need" through "targeted investments in transformational R&D that will ensure our nation's future through sustained technological leadership." See <*http://www.nist.gov/tip/*>. Despite its broad mandate, funding for TIP was modest, and no funds were appropriated for this program in the FY 2012.

program on its own. More recently, NIST has partnered with the Nano-Electronics Research Institute to provide funding to university research consortia, supporting early-stage technologies of broad interest to companies.

In closing, Dr. Singerman said he was interested in the lessons of Germany has learned from its expertise in manufacturing, and in bringing those lessons to the U.S. innovation eco-system. Conversely, he said, he hoped there were reciprocal lessons U.S. speakers were bringing to their German colleagues, perhaps including some of those supported by NIST. "I'm eager now or in subsequent communications to receive your views on these issues," he concluded, "and to discuss further the Obama administration's interest in manufacturing and its connections to innovation."

DISCUSSION

A questioner asked about the role of the U.S. government in terms of encouraging innovation. Ms. Lew said that the government tries to do this with "a light touch," offering them access to technologies of potential value that may be sitting unused in research laboratories, but "basically getting out of the way of entrepreneurs and allowing them to take risks. "I think it has to do with both culture and attitude," she said. "In the United States, we really do encourage risk taking and failure. We accept the fact that entrepreneurs can and should fail, because you don't always get it right the first time. We try to adopt policies that give access to the technology, reduce regulatory hurdles, and catalyze the access to capital without interfering with the private capital markets. We want to just be catalytic and remove some of the risk from the marketplace without getting too involved."

A questioner asked how much the U.S. regulatory requirements of the state and federal governments overlapped or conflicted. Dr. Singerman noted that there is a long-running ideological debate in Washington over whether the federal government should engage in "industrial policy," favoring certain technologies or industries. The official position is that it cannot, but the states all have some form of industrial policy, regardless of whether they have Republican or Democratic governors. NIST is very interested in working with the states, and many have close connections with federal funding sources. "Partnership is really the key to the national agenda," he said. "Unfortunately, with state budgets reduced, there's a gap in the ability to support small firms, if not in willingness."

Ms. Lew said that for 10 years she was on the supervisory board of a European investment fund that invested in early-stage companies. She learned how much young start-up companies were affected by restraints on company formation, limited access to private sources of capital, and employment regulations. In the United States, she said, there is considerable collaboration between the federal and state governments "because at the end of the day, if we have stronger regional economies, we have a stronger national economy." As an example she mentioned an index that ranks the states on how business-friendly they are. As such knowledge circulated, the states began to compete to score

high in the index. For example, 10 states have already established tax credits for angel investors. "I think goal at all levels of government," she said, "has been to find ways to collaborate and remove obstacles," she said.

The questioner also asked whether there were direct monetary incentives for open source innovation. Ms. Lew said that, again, the federal government intentionally tries not to intervene in such processes. The government does involve itself in some issues, such as cyber security, privacy, or consumer protection, "but I think, again, let the marketplace do what it needs to do, and we get out of the way."

Dr. Harhoff commented on similar considerations in Germany, such as the policy initiatives favoring the formation of innovation clusters. "It's a multi-level process with lots of folks and agencies becoming involved, and it poses its own difficulties." The German government also becomes involved in financing firm formation because the angel sector is so small. A student or private individual can apply for a founder's stipend worth up to 100,000 Euros from the Ministry of Economics. "We ought to do something about that," he said. "It should be private capital that finances these businesses from the early stage onward." On the other hand, he said, the share of R&D financed by the private sector in Germany is very high by comparison to the United States, and this adds to the stability of the innovation system.

Keynote Address

Werner Hoyer
Minister of State at the Foreign Office (Auswertiges Amt)

Dr. Hoyer expressed his pleasure at "sharing some thoughts on German-U.S. innovation policy, and the global challenges we must jointly strive to meet." He thanked the German Institute for Economic Research (DIW) and the U.S. National Academies for bringing together a distinguished group of experts, and shared the view that the preceding symposium in Washington was a successful preparation.

He said that he would like to make three key points: (1) the complexity of global challenges means that cooperation and competition in innovation go hand in hand; (2) the strong American-German economic relationship is the backbone of a cooperative innovation strategy; and (3) to remain competitive, the already vibrant U.S.-German innovation cooperation must be further strengthened.

Innovation, he said, implies something new; but not all things newly created are innovations. It is application, utilization, and ultimately marketability that turns an idea into an innovation. Innovation needs the market, and the market needs innovation. At the same time the challenges faced by innovators today are complex. "The aims of achieving prosperity for all in the face of limited resources," he said, "the challenges of climate change, energy security, food security—no one nation can address these challenges on its own. The more closely we work together, the more likely we are to find solutions. In a climate of healthy competition, Germany profits from U.S. prosperity, and vice-versa."

PARTNERSHIP BRINGS BENEFITS FOR BOTH SIDES

Elaborating on the second point, Dr. Hoyer said that the importance of strong American-American relationships becomes clear from the economic relationship between the two nations. The United States is Germany's most important trading partner outside the EU, and likewise Germany is the top trading partner of the United States in Europe. While the economic crisis slowed trade between the two nations, transatlantic trade has been increasing again since 2009. Bilateral trade amounted to $130 billion in 2010, up from $115 billion in

2009. The figures of foreign direct investment are equally impressive. In 2009, German companies invested an accumulated $334 billion in the United States, the second-largest amount by an EU country, behind the Netherlands. Germany was the fifth-largest foreign investor in the United States with investments of $116 billion. "We see that the transatlantic relationship has come a long way since the Marshall Plan," he said.[14]

In addition to the strong bilateral trade and investment relationship between the United States and Germany, Dr. Hoyer said, the two countries have also cooperated in overcoming the global financial crisis within the framework of the G-20. He said that "the collaborative effort is paying off," and that "the worst of the crisis is behind us." In Germany the GDP grew by 3.6 percent in 2010, the economy's strongest performance since reunification. He projected that the performance in 2011 would be at least as good. Total employment had also reached its highest level since unification, with a working population of 40.5 million in 2010. In the United States, growth had resumed also, at a rate of almost 3 percent in 2010, while unemployment was still high at 9 percent.

The occasional divergence of views between the two nations on how to handle the crisis, he said—such as the timing of fiscal consolidation—had so far "served less as an irritant than as a catalyst for more meaningful exchange." The reason was that Germany and the United States agreed on the fundamental goal of promoting sound, market-driven economic policies in democratic and free societies. "We argue that the role of the state in our two societies is to set the framework for economic activity," he said, "and provide incentives for innovation."

Ideas for innovations in both countries come from many directions, he said, including the universities, scientific organizations, think tanks, research institutes, and industry. The German government had just launched a new initiative for electromobility, or e-mobility, to provide the framework for research and development with funding of 1 billion Euros through 2013.

THE NEED TO COORDINATE NORMS AND STANDARDS

Another goal of the initiative is to strengthen international cooperation with regard to norms and standards. Cooperation on standards is an issue not only for the bilateral relationship, but also for the EU as a whole and the United States. Through the Transatlantic Economic Council (TAC), founded in 2007 on a German initiative, the United States and EU cooperate on future-oriented economic issues, including e-mobility. Germany has pushed for including e-mobility on the agenda of the council—again, the catalyze development of

[14]Under the Marshall Plan, which operated from 1948 to 1951, the United States invested $13 billion in European reconstruction. It also reduced trade barriers, encouraged cooperation, and launched other elements of European integration.

norms and standards which facilitate trade. Because the United States and EU are the world's most closely linked economic regions, jointly generating 54 percent of the world's GDP and providing 30 percent of its consumers, "this is not an unrealistic expectation," he said. With bilateral trade between EU and United States amounting to 15 and 20 percent of their respective trade volumes, and each being the other's paramount investment partner, the Transatlantic Economic Council can significantly facilitate trade, investment, and innovation at the same time.

In regard to the need to strengthen Germany-U.S. cooperation, Dr. Hoyer said that the Foreign Office actively contributes to this goal, as do the Ministries of Education and Science. "We believe that in order to remain competitive," he said, "the already vibrant U.S.-German innovation cooperation must be further enhanced." This cooperation, he said, spans a broad range of topics, institutions, and individuals, and is supported by universities, science organizations, research institutes, industry, foundations, and other stakeholders. Projects for bilateral cooperation range the International Space Station and the Stratosphere Observatory for Infrared Astronomy to basic research in physics, health, energy, and civil security. There is also cooperation on the development and use of hardware, including U.S. participation in the German electron synchrotron (DESY), the Large Hadron Collider at CERN, and a joint project linking the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory with the neutron spin echo spectrometer at the Technical University of Munich. The opening of the Max Planck Florida Institute in Jupiter, Florida, which focuses on bio-imaging, was another milestone in U.S. cooperation.

SCIENCE OUTREACH BY THE FOREIGN OFFICE

The Foreign Office also funds academic exchange programs and scholarships that enable American students and scientists to visit Germany. The growing number of participants reflects the increasing importance of research cooperation as a "pillar of German foreign policy." Over the years, 20 of the numerous American scientists granted the Humboldt Scholarship to work in Germany received Nobel Prizes later in their careers.

The Foreign Office also operates the German Center for Research and Innovation in New York, which it established in 2010. Dr. Hoyer described it as a cornerstone of the German government's strategy for international science and research. The center, located near the United Nations, has already strengthened Germany's visibility as a hub for science and innovation; since its founding, it has hosted 15 major events for American and German partners of science and business and "is making a significant contribution to transatlantic cooperation to help solve global challenges of the 21st century."

Also, the U.S.-German Framework Agreement on Scientific and Technological Cooperation, concluded in 2009, adds a strategic component to bilateral cooperation. The first meeting of the joint commission was scheduled for the following month under the title Priorities, Opportunities, and Concrete

Projects for Enhanced U.S.-German Cooperation in Science, Research, and Innovation.

Strengthening cooperation with the United States is part of the German government's strategy for the internationalization of science and research, Dr. Hoyer continued. The central purpose here is to address the challenge of global competition. "And this is going to be the hour of truth," he said, "because the dynamics of development in other parts of the world is overwhelming. If we do not meet these challenges, if we do not interest our young people science and technology, we are going to lose the technological leadership positions we still have."

The United States remains the world's leading nation in science, technology, and innovation, he said, "and thus our preferred and most important partner in this field." The technological leadership of the United States continues to be built on the contribution of foreign-born scientists and engineers, both permanent immigrants and those who return to their homes. In Europe, Germany is the top location for research, and currently Europe's engine of economic growth. "However," he said, "we need more flexibility to allow the immigration of the highly skilled, and to offer additional incentives to attract more scientists, engineers, and other highly qualified people from outside the EU to boost our innovation and productivity."

Germans closely followed President Obama's State of the Union address in January 2011, he said. Dr. Hoyer interpreted the president's central message to be "'winning the future through innovation and creating sustainable jobs and prosperity.' I couldn't agree more." He said that both the United States and Germany have realized they must give priority to research, science, and education. "Only an innovation-friendly climate and technological progress will allow for sustainable growth, employment, and prosperity." He said that in Germany, government funding for science, research, education, and innovation was set to rise by 12 billion Euros between 2010 and 2013. The objective is to invest 10 percent of GDP in research and education by 2015—3 percent in research and 7 percent in education. With research and development amounting to 2.8 percent of GDP in 2009, he said that Germany already ranks among the world leaders in this respect, "but we still have a long way to go."

STRENGTHENING TRANSLATION OF RESEARCH RESULTS INTO PRODUCTS

In particular, Dr. Hoyer said, Germany needs to further strengthen its expertise in translating research results into new products, services, and procedures. The German government aims to do this partly through enhanced cooperation between research and business. The government's High-tech Strategy 2020 identifies a number of concrete translational goals, such producing as 1 million electric vehicles by 2020, and CO_2-neutral, energy-efficient cities. The EU's own 2020 strategy places education, innovation, and research at the center of European growth policy. In contrast to the tepid

response to the Lisbon declaration, he said, the EU is now taking seriously the need for more effective technology translation.

In addition, he said, both countries would have to prepare for possible new security challenges in the 21st century, such as asymmetric threats. Given the importance of foreign trade and the vulnerability of critical infrastructures, a U.S.-German agreement on cooperation in civil security research was signed in March 2009. It was designed to produce mutual benefits on issues such as visual analytics, cargo security, and detection of hazardous substances. Similar collaboration is under way in climate change research.

Dr. Hoyer concluded by urging even greater cooperation in the fields of renewable energy and energy efficiency, which he called "one of the most decisive markets of the future. The United States and Germany are in a perfect position to lead the development of these markets. If we pool our resources and creativity, the breakthrough of renewable energies worldwide will make our world more secure, more affluent, will help the environment, and create thousands of new jobs in both our countries."

Panel II

Competition and Cooperation in a Global Economy

Moderator:
Katharina Schlüter
Finance-Magazin

Ms. Schlüter set the tone for the second panel by summarizing some changing features of the global economy. For many decades, she said, Germany and the United States had dominated the world in economic competitiveness, while countries such as China and India had provided cheap labor at the expense of environmental and social standards. She noted the emerging countries' argument that they had no obligation to slow growth for the sake of lowered global warming, since the problem had been initiated mainly by industrialized countries.

This situation was rapidly changing, she said, as India, and especially China, have emerged as serious global competitors for customers as well as for natural resources. But many people feel that this emergence was propelled by a free-rider mentality, lax intellectual property rules, favorable exchange rates, and trade barriers. She introduced the second panel with a series of interrelated questions: What can German and U.S. companies do to better compete and cooperate in the face of newly competitive countries? What can universities and governments do to support these companies? Is there a way for emerging economies to grow without harming the environment?

CHINESE AND INDIAN INVESTMENTS AND ECONOMIC STRATEGY

Carl Dahlman
Henry R. Luce Associate Professor
Georgetown University School of Foreign Service
and
Member, U.S. National Academies Committee
on Comparative National Innovation Policies

Dr. Dahlman said he would discuss how the emergence of China and India as economic powers was creating a new global balance. One feature of this change was a period of tremendous uncertainty, he said, including the recent financial crisis that has affected not just developed countries but the whole world. Another feature was a new cast of competitors who are changing the global landscape. He mentioned also several new "binding constraints," including global climate change and higher costs of capital that are "in the offing."

One way to measure global change, he said, was in terms of purchasing power parity over the past three decades. The economically advanced countries, he said, had been generating about 64 percent of global GDP in 1980, but this figure had dropped to about 53 percent in 2009. China had risen from earning from 2 percent of GDP to 12.5 percent, and India had rise from 2.24 percent to 5 percent. The EU had lost relative share, dropping from 18.5 percent in 2000 to 15 percent in 2009; it had also lost population while the developing nations rose. The United States had dropped in PPP from 22.5 to 20.5 percent.

The economic crisis that began in 2008 also affected China and India differently. The crisis had the largest impact on the developed economies because it emerged from the financial sector of the United States and Europe, and spread elsewhere from there. GDP growth in developing countries did not turn negative in China and India, but continued to grow at 8 to 9 percent per year; both countries are expected to continue to grow three to four times faster than the rest of the world. Africa is also growing relatively fast, he said, primarily because of an interdependent relationship with China, to which it exports commodities.

As the largest of the emerging economies, China and India are becoming more important not only in terms of trade, but also in activities related to tertiary education, science and engineering, journal articles, patenting, inward and outward foreign investment, and geopolitical policies, many of which place increasing pressures on the global economy and the environment.

Two Millennia of Economic History

Dr. Dahlman reviewed the last two millennia of economic history and the relative dominance of China and India. For the first thousand years, he said,

China and Indian represented roughly one third and one quarter respectively of the entire world's economic activity in terms of purchasing power parity. India's share has declined during most of the second millennium, turning steeply downward around 1700 to only a few percent, while China's share peaked at around 1820 and then dropped even more steeply to about 5 percent by World War II. Meanwhile the share of Europe, at around 10 percent for the first millennium, began a steady rise around 1000, accelerating during the industrial revolution to about a third of all economic activity by 1870 while the whole global pie expanded. After a 40-year plateau of dominance, Europe began a decline after World War I that continues today. The United States soared from near zero in 1700 to a peak of about 27 percent in 1950, when it, too, began to turn down. Just about then, China's share was bottoming at around 3-4 percent and it began the rapid reversal that continues today; its share is today about 14 percent as it rises toward the downward paths of the EU and United States.

Warning that projections of economic growth cannot be precise, he said that at least an approximate picture could be drawn for the next decade or so. Citing IMF data for growth rates of the eight largest economies from 2000 to 2010, he discerned "a strong indication that in terms of PPP, China's economy will be as big as that of the United States around 2016, and then it will become larger." India's economy, he said, will move into third place (passing Japan) and continue its own climb at a slightly slower rate than China. These changes would occur slightly more slowly if calculated in nominal exchange rates or adjusted for overvalued currencies, but the trends would be consistent. "Both China and India face big challenges," he said, "and history is not linear. But both China and India are becoming large players on world scene, and are likely to become larger and more important over time."

Generous Investments in Education

The trend in both China's and India's growth is accompanied by generous investments in education, especially in the case of China, which by 2007 already had more students at the tertiary level (25 million) than the United States (17 million) or India (almost 13 million). China also graduates about seven times as many graduates in science and engineering at the baccalaureate level as the United States. While the quality of graduates at this level is criticized, a similar picture emerges at the PhD level, which is considered generally sound. Using data from the National Academies, he showed that 15 years ago, China produced only about 2,000 science and engineering PhDs; by 2007 this figure had risen eleven-fold to 22,000. In the United States the population of PhD graduates rose from 17,000 to 23,000 in the same period, but the number includes about 11,000 foreign-born PhDs, so it is really only half as large. In addition, Chinese students studying in China are staying in China; Chinese and Indian students in the United States are staying for shorter periods and returning home in greater proportion to well-paying opportunities in companies and university labs.

One outcome of the expanded pool of Chinese being educated in science and engineering is a larger population of researchers. Between 1995 and 2007, the total number of researchers in the United States rose by 27 percent to 1.4 million, while the number of researchers in China almost nearly tripled to nearly the same total.

Dr. Dahlman then showed a graph plotting R&D spending as a percentage of GDP against R&D researchers per one million people for 2007. The United States was spending the most, with a value of 381, and Japan was second at 143. If the numbers are adjusted for 2010, he said, China would now be the largest. From 15 years ago, China has changed from spending 0.5 percent of GDP on R&D to spending 1.6 percent today; it plans to increase this share to 2 percent in the next few years, and to 2.5 by 2020. "They are not as efficient as the United States yet because they are learning how to improve their management skills," he said, "but they are investing heavily in that."

Science and Engineering Outputs

He reviewed some of the outputs resulting from this effort. Between 1988 and 2008, China's production of science and engineering articles rose from near zero to about 60,000, surpassing Japan and Germany. In patent applications between 1883 and 2008, China has risen from virtually zero in the late 1980s to about 300,000, third after only the United States and Japan.[15] In trademark applications, again mapped from 1883 to 2008, German and then Japan were leaders, and then China had soared ahead in domestic applications. "They are making a very big effort," he said, "going from a focus on imitation, which they have done well, to tapping global knowledge, to beginning to invest on their own account. They still have a long way to go in terms of quality, but in many areas they're moving to be leaders in scientific and technical publications."

China is having big impact, because of its larger size, faster growth, greater integration to the international system, and more strategic government, he said. India is still much farther behind, but is catching up and "will have the level of investments China now has in about 10 years. It will be the world's third-largest economy in PPP by 2014, and fourth-largest in nominal terms by 2021."

Benefits and Challenges from China and India

The rapid growth of China and India, he said, brings many benefits. China, in about 15 years, has lifted about half a billion people out of poverty. It has created growing markets for goods and services. According to IMF data,

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[15]He cautioned that patent data are uneven because the rules differ by country, with some countries, including China and Japan, allowing patents for "smaller pieces of the pie."

more than 50 percent of net world growth between 2008 and 2011 has been generated just by China. "Of course we are happy to see that. That means opportunities for exports of goods and services, and foreign investment. And of course when they produce anything, they create competitive pressures which lower the cost of goods and services they export." China is also a growing source of capital and direct foreign investment abroad. The country has been an important investor in U.S. treasuries, so that even though China is a poor country in terms of per capita GDP—which is about $1/15^{th}$ that of the United States—they are a net capital exporter. About three million students are studying outside China at the tertiary level, contributing to the research effort of developed countries. Increasing R&D and innovation help the world to improve the use of resources and address other global issues.

At the same time, their rapid growth brings challenges. Their low-cost dominance of some foreign markets brings economic suffering to domestic U.S. industries. China maintains a market reserve for particular products they manufacture. They demand a great deal of technology sharing, such as source code, from foreign partners in joint ventures; they restrict access to their markets; and they impose government procurement rules and standards, all of which create frictions. IPR piracy continues to drain profits from companies. "What is happening," he said, "is a gigantic rebalancing of relative wages between these two hungry new entrants and the developed world. The total world labor force has increased by a factor of four between 1980 and now, and a large part of the change is China."

Putting Pressure on the Environment

Dr. Dahlman turned to the effect of this rapid growth on the environment, showing a graph of the ecological footprint of the 10 largest "users" of the environment in 2007. The ecological footprint is the total area of land and sea used by people, included the area needed to provide resources and absorb wastes, such as CO_2 emissions. In 2005 the United States had the biggest footprint; by 2007, when the latest data were compiled, China had the biggest. He said that by one accounting method, China has a net environmental deficit equivalent to 14 percent of the world's bio-capacity. Europe as a whole has net deficit of 12 percent, the United States of 10 percent, and India of 4 percent; Brazil and Russia have surpluses. "This shows that the way we are doing development is not sustainable," he said. "And these two countries are putting a lot of pressure on the global system. So we have to rethink our development models toward major investments in innovation. We're not yet doing enough at a global level."

One reason for this, he said, is that governance at the global level is not up to the challenges. Each country pursues its own natural advantage at a country level, paying little attention to the global system. "To some extent," he said, "China has benefited by free-riding in terms of rules of trade, exchange rate, IP, piracy, and now using its very large market to draw technology from the

rest of the world. We have to discuss how to allocate resources, both physical and human, and provide social safety nets." He listed a series of topics for which global cooperation is urgently needed:

- Preparing with pandemics.
- Improved energy efficiency and alternative energy technologies.
- CO_2 sequestration.
- Diseases of aging populations.
- Natural resource technologies.
- Sustainable development strategies.

Dr. Dahlman concluded that nations now share a "demanding, dynamic, and uncertain global environment" with big new players and many possible uncertainties, from another financial crisis to internal problems disrupting China. "This talk is meant as a stimulus to understand that the world is in tremendous flux, with big challenges, and big constraints. It is an invitation to our North Atlantic alliance to better collaborate in rebalancing our global systems."

INNOVATION AND TRADE

Alan Wm. Wolff
Dewey & LeBoeuf LLP
and
Chair, U.S. National Academies Committee
on Comparative National Innovation Policies

Ambassador Wolff said he had learned from Professor Dahlman's talk much about the world economy on the macro scale—a broad view of the global system "from 30,000 feet." He said he would now offer a closer look at several particular economies, especially those of Taiwan and the People's Republic of China, "from 10,000 feet," in order to understand how very organized societies, led by their government, could influence their standing in that same global system.

He said that he had spent years as a trade negotiator with Japan, and that its growth had begun through dependence on a state-industrial partnership, a closed home market, and a form of state-run capitalism. Taiwan was also resource-poor, and decided to adopt much the same strategy—a state-led, market-oriented innovation policy. Part of the strategy was the emulation of the large U.S. research parks, such as Research Triangle Park, Route 128 in Boston, and Silicon Valley. Taiwan assembled its own version, the Industrial Technology Research Institute (ITRI), in 1973, followed by Hsinchu Science Park in 1980 and Southern Taiwan Science Park in the 1990s.

The Strategy of ITRI

ITRI's strategy was to invest in infrastructure, with government partnership, through the purchase of common facilities, equipment, and tools for strengthening existing facilities—much as Japan had entered the semiconductor business and began building integrated circuits. Japan pooled the knowledge of the big labs, brought in the six vertically integrated electronics companies, and quickly developed first the 64 DRAM and then the 256 DRAM, overwhelming both European and U.S. competitors.

ITRI propelled local industry by disbursing seed money to universities, other research institutions, and separate projects focused on key technologies and components. Products were moved through 13 ICT research units from incubators into the private sector. Priority fields were identified, including ICT, advanced manufacturing, biomedicine, nanotechnology, materials and chemicals, and energy/environment. A hub linking science parks, universities, and companies in Taiwan's north, central, and southern zones was established to coordinate the whole innovation system.

70 Percent of the World's IC Foundries

In 1979, the semiconductor make UMC became ITRI's first spinoff; TSMC followed eight years later, in 1987. By 2006, TSMC and UMC controlled 70 percent of the world's IC foundry business. By the Q4 of 2010, Taiwan's revenue share of the world IC industry was about 18 percent.

Having become largest notebook producer in the world, ITRI went on to pull together 47 of its companies as a Notebook Computer Alliance in 1990 to promote production cooperation. This helped to transform Taiwan into the world's fourth-largest producer of IT hardware. By 2006, ITRI had sent 17,000 alumni into Taiwan's workforce, some 5,000 of whom were working at the Hsinchu Science Park where they founded many new companies.

During Taiwan's transformation into a knowledge-intensive economy, ITRI has continued to focus on its priority areas, which are now:

- ICT.
- Electronics and optoelectronics.
- Materials, chemicals, and nanotechnology.
- Medical devices and biomedical research.
- Mechanical systems.
- Green energy and environment.

China's Strategy of Indigenous Innovation

The development of China really began in 1978, he said, when Deng Xiaoping opened its economy to the outside world and began a major drive to

attract foreign direct investment. FDI was originally capital but was gradually supplemented by research and development capacity in the form of returning scientists and engineers of the Chinese Diaspora. China, like Taiwan, also supported indigenous innovation through university R&D, national labs, science and technology parks, and a strong IP environment. China's strategies and assets included:

- Very rapid GDP growth.
- A large domestic market.
- High penetration of cell phones and Internet.
- Investment in STEM education, especially in engineering.
- Welcoming FDI and incentivizing technology transfer.
- Incentives for indigenous patenting.
- Ability to fully mobilize national resources, with state planning for huge science parks.

The results of this program emerged rapidly. "In 1988," he recalled, "you looked across the river from Shanghai to Pudong and saw only fields. If you go there today it's one of the world's largest S&T parks, full of high-tech companies from the United States and Europe, all contributing to China's growth." Overall, China has 54 state-level economic and technological development zones, and 53 national high-tech development zones. The average size of major science parks in China 10,357 acres; Research Triangle Park (RTP) in North Carolina is 7,000 acres, while the average North American research park is 358 acres. The power of successful parks is considerable; when the RTP was founded in 1950, North Carolina ranked 49th in per capita GDP; currently it ranks in the top 10.

However, Mr. Wolff cautioned, state planning is not always completely successful. "Whenever you launch an industrial policy in a specific direction, you always overshoot." As examples he cited overproduction of steel, which Europe did, and China did later; and overproduction of solar panels and wind turbines by China. "State planning, with the vestiges of Marxism, can be a mixed blessing when there is little independent thinking," he said, noting that China's required courses on Marxism in some engineering schools are unlikely to foster engineering creativity or top-quality graduates. Other drawbacks of the state-run economy include continued dependence on FDI, inadequate protection of IPR, and sometimes heavy-handed attempts to force transfer of technology from foreign joint venture partners.

China's current leaders, many of whom are engineers, have become more sophisticated. "Achieving indigenous innovation" has become a slogan, and current goals include intensive investments in crucial high-technology products, and the use of policy tools to promote indigenous innovative technologies, increase R&D spending to 2.5 percent of GDP by 2010, and support state projects to generate important strategic products.

Difficulties for Potential Partners

At the same time, Mr. Wolff continued, the enthusiasm for "made in China" and desire to control joint ventures brings difficulties for potential partners:

- China delayed the introduction of 3G wireless technology until it could be manufactured domestically.
- About 80 percent of consumer electronics standards are tweaked just enough to create barriers to selling in China.
- The use of a Trusted Computing Module (TCM) forces encryption for computers with a domestic standard.
- Automobiles cannot be more than 49 percent produced by a foreign company, and new rules require that Chinese brands be used.
- For wind electrical generating equipment, purchases are controlled through the use of standards, skewed procurement, and indigenous innovation. Between 2004 and 2010, wind equipment sales by Vestas, GE, and Suzlon dropped from 70 percent of the market to 13 percent because no large project of the National Development and Reform Commission has resulted in a purchase of any wind equipment from any foreign producer.
- China planned to have all supercomputer ICs made by indigenous Chinese firms by the end of 2011.

Longer term, the government plans to continue its "make it in China" S&T strategy. Key state projects require almost all technologies, from ICs to aircraft to manned space flight, to use indigenous Chinese components. Other technologies that are restricted to Chinese-made components include:

- Core electronic components.
- Extremely large integrated circuits.
- Broadband.
- Numerical controlled machine tools.
- Oil and gas fields.
- Large nuclear power plants.
- Gas-cooled reactors.
- Genetically modified biological species.
- New drugs.
- Control and treatment of major contagious diseases.

Mr. Wolff summarized by reviewing the universe of government strategies used to promote innovation, which ranged from "sort of a Washington consensus of a market orientation" to the Beijing strategy of "techno-nationalism." The Chinese strategy, he said, faced the challenge of achieving indigenous innovation while closing its markets to competitors. "We have much

to learn from Germany in this range of possibilities," he concluded. "What we see is that nations do take policy measures to improve their position vis-à-vis each other. We're suffering everywhere from budget deficits, which puts pressure on federal innovation programs. Yet we must continue to invest in universities, small businesses, research parks and clusters, and new emerging technologies. We must reform immigration to attract and retain the best and brightest. And as we have learned from our partnership with Germany and other EU nations, we must continue our international cooperation on mutual long-term goals and strategic partnerships on specific research issues."

DISCUSSION

A questioner asked how the panelists would compare immigration policies and brain drain issues in the United States and Germany. Dr. Dahlman said that part of the reason the United States has been so successful in innovation is that it has attracted the best and the brightest from all over the world. It has offered a supportive environment, access to venture capital, and favorable rules and framework conditions. However, he said, since 9/11 the nation has had almost free trade in industrial goods, somewhat constrained trade in agriculture, but no free trade in people, except at the very highest levels. "Now there are very attractive opportunities back in those countries," he said, "so Chinese and Indian firms are actively recruiting graduates in the United States—not just their own nationals, but other nationalities. So there is a reverse brain flow." The market for talent is global, he said, and the competition is heating up. Each country wants the most entrepreneurial and inventive people—the core of competitive advantage. So each country's immigration environment and support policies are important.

Engelbert Beyer, Head of the Directorate for Innovation Strategies, Federal Ministry of Education and Research (BMBF), asked about the U.S.-Chinese bilateral innovation platform, and the content of some general government consultations that had taken place two weeks earlier. He asked what the panelists would suggest as a sound diplomatic strategy for Germany and Europe at this time "in regard to this rising superpower."

Ambassador Wolff said that the talks had concerned the issue of Chinese "catalogues" of products with Chinese IP that formed the basis for government procurement. Hu Jintao had said the previous January that the Chinese government would no longer be limited to buying products from the "all Chinese" catalogues, but that change was not translated into Chinese, and nothing changed within China. In May, the U.S. treasury secretary and secretary of State, meeting with their opposite Chinese numbers, persuaded them to tell their procurement people about that change and remove the catalogues.

A continuing problem, he added, was that while the Chinese no longer have to "buy Chinese," can still do so, and they do not need to buy non-Chinese. "Having said for seven years or so that you ought to buy Chinese IP-intensive goods from Chinese companies," he said, "that habit has sunk in deeply at the

state-owned enterprises. The fact that formal government procurement might be open some day without the use of these catalogues is a very minimal step. This evolution resembles Japan, which didn't open its procurement until economic forces induced it to open up."

On the positive side, he said—in health issues, climate change, and others, where Germany and the United States face common threats—there is room for cooperation. "Non-Chinese companies are betting that China will eventually buy wind equipment from them; otherwise, Vestas and GE and Suzlon would not be doubling their bets in China, which is what they're doing. Their hope is that things will turn around."

Dr. Dahlman suggested that "what we need to do in the dialogues is to have very frank, tough talk." He underlined the problem of the Chinese government's industrial policy, which includes both requirements of technology transfer and rules that make it difficult for foreign firms to compete. Because the market is so large and fast-growing, he said, the firms continue to go to China for short-term returns, even though they operate at a disadvantage in an uncertain climate.

Charles Ebinger of the Brookings Institution raised several questions about energy. He questioned the fate of the nuclear reactor industry that seemed to rest on a confluence of trends: Germany is discussing the abandonment of nuclear power, the United States is restrained by economic factors from building new nuclear plants, and China plans to become a major vendor in the nuclear marketplace. This, he said, would seem to weaken the opportunities of GE, Siemens, and other traditional vendors. Also, he said, the Chinese, who are heavily dependent on coal, are now building "the best coal plants in the world" and "moving rapidly to prove that sequestration of CO_2 can work."

Ambassador Wolff noted that "China is run by engineers who have a clear conception of problems they face." As coal represents an increasing proportion of their energy use, they realize its costs in terms of pollution. At the same time, China has the largest wind energy installation to date, and is pressing ahead on its renewable energy infrastructure.

Panel III

Human Resources, Competition for Manpower, and the Internationalization of Labor

Moderator:
Irwin Collier
John F. Kennedy Institute
Free University Berlin (FU Berlin)

Mr. Collier introduced the third panel, noting the "smooth transition" from the discussion of the previous session on the globalized market for talent. "Human resources," he said, "as we have seen, are very much a constraint or an opportunity for innovation policy." He then introduced the two panelists, Klaus F. Zimmermann of the Institute for the Study of Labor (IZA) and the German Institute for Economic Research (DIW Berlin), and Jan Muehlfeit of Microsoft Corporation.

THE HUMAN RESOURCE CHALLENGE

Klaus F. Zimmermann
Director, Institute for the Study of Labor (IZA)
and
German Institute for Economic Research (DIW Berlin)

Dr. Zimmermann said that his current research emphasis on migration and labor markets was "well suited to this important gathering," and that in the future, human resources "will be even more than in the past the central part of innovation creation, along with the use of new products and services."

A point he emphasized was that the success of new ideas has to do not only with the "intelligent and market oriented creation of products and services," but also with the willingness of an educated population to use what is invented. "So I think human capital is in the center of innovative activity. If you talk about innovation policy, you cannot forget education policy, migration policy, and mobility policies. All are issues where we see lots of challenges coming, especially in Europe, which is mobile and has deficits in its education system."

This was particularly true for Germany, he added. "On the other side of the Atlantic, the United States has at least a legendary tradition in immigration policies that attract the best of the world. But there is the question of what Germany can provide in this debate. I don't think we should be pessimistic, but we have things to discuss. We have to understand that the future depends on a common effort to face the challenges, especially from the rise of Asia."

Migration and Innovation

Dr. Zimmermann said that the IZA, based in Bonn, has the largest corps of scientists in economics in the world—about 1,100—who cooperate with researchers in United States and China. He summarized his work at IZA and the University of Bonn from the position that innovation, migration, networks, and mobility go together. More specifically, he said, people with diverse socio-cultural backgrounds may boost the creation of new ideas, knowledge spillovers, entrepreneurship, and economic growth. In other words, innovations are based on knowledge and human capital. Migration may cause innovations, for many reasons, such as destroying and restructuring old ideas and replacing them with new ideas. Also, he said, labor mobility carries knowledge. "Innovation is a product of knowledge and ideas being transmitted between people with different information sets through personal contact."

He cited several recent IZA Discussion Papers that elaborated on these points. In the first of them "the authors have convincingly found that it's not the quantity of migration but the diversity of the immigrant population which has stronger effect on patent applications. Also, the average skill of immigrants matters very much. Given that Europe attracts not the skilled migrants of the world, this is very important finding."[16]

The second paper Dr. Zimmermann emphasized examined labor mobility and concluded that its effects do not depend on whether people move from outside or inside the country.[17] "It's true that the exchange of people between companies is very important," he said. "If new people come in, it increases the likelihood of innovation—especially if they come from innovative companies." This may seem obvious, he suggested, "but it's also true that if someone leaves a company and goes to another innovative firm, this also has positive effects on the innovative activity of his old company. This means that

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[16]Ceren Ozgen, et al, "Immigration and Innovation in European Regions," IZA Discussion Paper No. 5676, 2011. Prof. Zimmermann commented: "Distinct composition of immigrants from different backgrounds are a more important driving force for innovation than the sheer size of the immigrant population in a certain locality."

[17]Ulrich Kaiser, et al, "Labor Mobility, Social Network Effects, and Innovative Activity," IZA Discussion Paper No. 5654, 2011. Prof. Zimmermann commented: "Labor mobility between firms is associated with an increase in total innovative activity of both the old and new employer"; "Social network effects are the channel for this mechanism."

there is interchange that helps improve the information flow between people who have left and those left behind. So there's an increase in innovative activity for both companies."

The Human Resource Challenge

Dr. Zimmermann turned to the "human resource challenge," and the "need for good people." Demographic trends indicate that there will be an "enormous shortage" of high-skilled workers around the world. This is already apparent today, he said, and will become "more dramatic." It is not only a problem for Germans and Americans, but also for the Chinese. He added the following details:

- High-skilled workers are the driving force of innovation.
- The competition for high-skilled workers is global.
- High-skilled workers are mostly university graduates.
- Therefore, higher education policies and human capital strategies are crucial.
- A likely scenario is that in 20 to 30 years, the United States will still be the dominant global force for innovation, along with China, while the rest of the world lags.

He noted that the brightest people in the world still want to study in the United States, and to earn a doctoral degree there. "And of course the very best stay in the country. The less well qualified go home and build up a network with the United States." Europe, on the other hand, "has never wanted to be part of this game, and I think this has to be rethought." This, he said, requires the reformation of German and European universities.[18]

Dr. Zimmermann showed a graph comparing enrollment in higher education in the US, China, and Germany in 2005. It showed that China was already ahead in absolute numbers, but behind both the United States and Germany in enrolled students as a percentage of their age group. He noted that China's government has "strong ambitions" to increase enrollments.

[18]He recommended a recent book by Jo Ritzen, *A Chance for European Universities: Or: Avoiding the Looming University Crisis in Europe,* Amsterdam University Press, February 2011. Ritzen, former rector of Maastricht University, is now a colleague of Dr. Zimmermann at IZA. Previously he served as Minister of Education, Culture, and Science of the Netherlands, as well as vice-president of the World Bank in the Development Economics Department. His book has been published in German as Eine Chance für Europaische Universitaten, by Königshausen & Neumann, June 2011.

China is already ahead in absolute numbers, but there is still substantial scope in relative enrollment rates when compared to the US and Germany

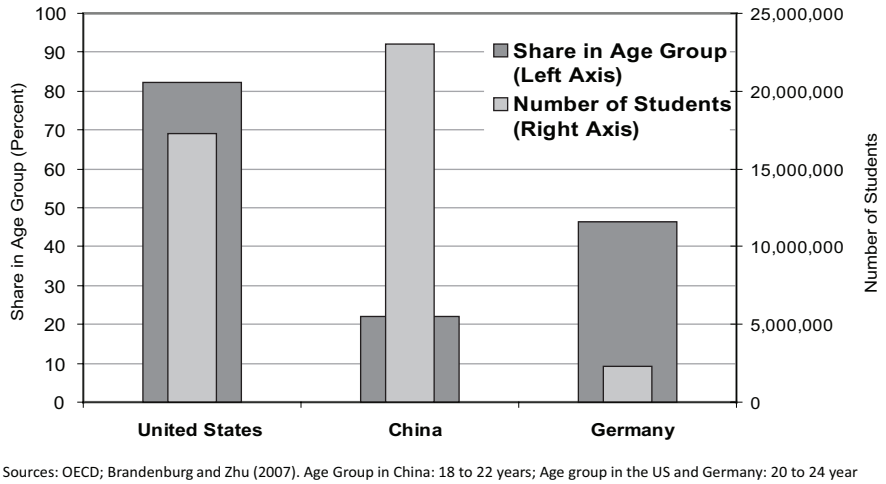

FIGURE 01 Enrollment in Higher Education (2005).
SOURCE: Klauss F. Zimmerman, Presentation at the May 25-26, 2011, National Academies Symposium on "Meeting Global Challenges: German-U.S. Innovation Policy."

European Economists Have Gained in Importance

Dr. Zimmermann then made the "controversial" point that the success of universities depends on the success of university education, which in turn depends on the quality of their research—more than the quality of their students. "Some people do not like that conclusion," he said, "but that's how it is and should be. It is good news if we want to attract the best students and generate knowledge and then translate that knowledge into innovation." He said that when he began his own post-graduate education three decades earlier, Germany was far behind. "Europe was empty. Economics research was dominated by the West. Since then, there has been a big change, and European economists have gained in importance." As measured by its share of articles in economics journals, Europe between 1991 and 2006 had risen from about a quarter to about a third, while North America's share shrank from about 2/3 to less than half. Asia's share doubled, from a low base. "This is likely related to the Bologna process that facilitates the internationalization of research and teaching." He said

that except for the 10 best universities in the West, European researchers publish more papers per university.[19] In addition, he said there was a three-fold increased in the number of publications by German economic research institutes in SSCI-listed journals between 2000/01 and 2005/06.[20] In addition, he said, the number of articles published by DIW Berlin in SSCI-listed journals rose from 59 in 2008 to 78 in 2009; less than 10 were published in 2000.[21]

In short, he said, the process of catching up is still incomplete, with the per-capita number of publications in economics journals in Germany still substantially lower than in the United States. But the gap has closed since the early 1990s, he said, with international cooperation in Europe and across the Atlantic identified as an important factor.[22]

China's Push for Strength in S&E

Dr. Zimmermann widened his comparison to include a broader picture of science and engineering. Between 1988 and 2008, the number of S&E journal articles by European authors had risen from 146 to 233, while the number by U.S. authors rose less, from 170 to 199. The increase in Asia was far more dramatic, however, rising by a factor of 12, from five to 61, primarily because of the increase from China.[23]

China is pushing hard to increase its strengths in science and engineering, he said, including remarkable programs to invest money and apply development strategies to recruit the best people. "I have met with people who are organizing this for China," he said, "and they have a very public plan to be the world's scientific leaders by the year 2050." Among the milestones since the opening reforms of 1978, he said, were the following:

- Dramatic increase in the number of students enrolled in Chinese higher educational institutions (reaching 20 million in 2008).
- An increasing trend of Chinese students studying abroad (1.4 million in 2008).
- Tremendous scholarly output by China, with clear priority in natural sciences (59 percent of the articles overall).

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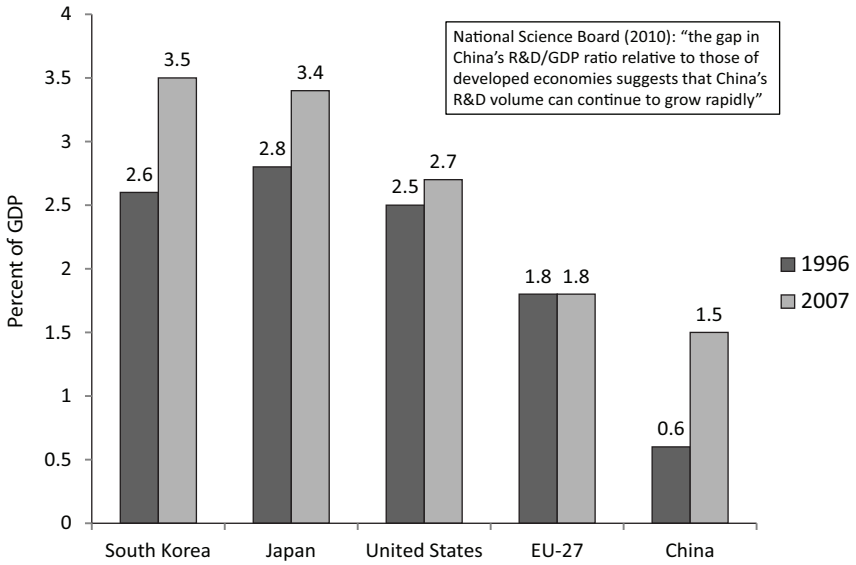
[19] *The Economist*, February 17, 2011.
[20] Rolf Ketzler and Klaus F. Zimmermann, "Publications: German Economic Research Institutes on Track," *Scientometrics,* 80(1):233-254, 2009.
[21] Annual reports of German economic research institutes, Zimmermann calculations.
[22] Ana Rute Cardoso, Paulo Guimaraes, and Klaus Zimmermann, "Trends in Economic Research: An International Perspective," *Kyklos,* 63(4):479-494, 2010.
[23] National Science Board, *Science and Engineering Indicators 2010*, Arlington, VA: National Science Foundation, 2010; Amelie F. Constant, Bienvenue N. Tien, Klaus F. Zimmermann, and Jingzhou Meng, "China's Latent Human Capital Investment: Achieving Milestones and Competing for the Top," IZA Discussion Paper 5650, 2011.



Source: Constant, Tien, Zimmerman, and Meng (2011, IZA DP 5650);
Based on National Science Foundation: Science and Engineering Indicators 2010

FIGURE 2 China on the fast track…and there still is scope for improvement. SOURCE: Klauss F. Zimmerman, Presentation at the May 25-26, 2011, National Academies Symposium on "Meeting Global Challenges: German-U.S. Innovation Policy."

- More International students studying in China (almost 200,000 in 2007).

Dr. Zimmermann concluded by emphasizing the importance of the "global tug-of-war" for talent, and reiterated that "whoever wins the battle will be the victor in the 21st century." He closed by reporting part of a conversation between Richard Freeman, a noted labor economist at Harvard, and a Harvard physicist who works closely with overseas scientists and engineers. Prof. Freeman said to the physicist, "Ah, so you are helping them catch up with us?" The physicist answered, "No, they are helping us keep ahead of them!"

A MICROSOFT PERSPECTIVE ON THE UNITED STATES AND EUROPE

Jan Muehlfeit
Chairman Europe
Microsoft Corporation

Dr. Muehlfeit introduced himself as a software engineer by profession, but "always interested in the relationship between technology and human beings." When he was born, he said, the price of a transistor was one dollar; today a dollar will buy one billion transistors. "This is driven by Moore's Law," he said, "and that will influence everything for the next 10 to 15 years." He said that the CEO of Daimler Benz had told him there are 19 "full-fledged computers" in a new car, and that Daimler's budget for software was 60 percent of its total budget. "Cars are in fact software products," he said. "If you look at all the skills around the industry, whether for a software engineer, a designer at the top of the pyramid, or a services man at the bottom of the pyramid, the skill set of everybody will move up because of the technology."

The New Era of Cloud Computing

Another big change would be the advent of cloud computing, he said, which would play as large a role in the knowledge era as electricity played in the industrial era. "What cloud computing means is that ICT will be delivered as a utility. That will bring huge cost savings, productivity, and innovation." Today, Dr. Muehlfeit said, a typical state organization may have to allocate 90 percent of its ICT budget to maintenance costs, leaving little for innovation. "Once you deliver software services through the Internet as a utility, you move your spending model from capex to opex, and that will change everything."

The "cost savings, productivity, and innovation" of the cloud were critical for Europe, he continued, because of three challenges shared with the United States. The first is debt; the second is demography, with both regions having to confront an aging population; and the third is the need to raise GNP growth. "We need to run faster today than we ran yesterday, but we also need to run faster than the others. While in Europe run fast in some ways, we lag behind in growth."

Another challenge, Dr. Muehlfeit said, is to revitalize education. Technology itself would not be a sufficient advantage, because it spreads so quickly around the world that it becomes a commodity. "We will mainly compete as human beings and organizations," he said, "but also as countries through our ability to unlock human potential." This can be done only by "improving education at one end and lifelong learning at the other. We need to introduce a startup mentality." He reviewed the case of Korea and Ghana. In 1950, the GDP per capita was about the same in both countries, whereas today Korea has soared far ahead. "It's very different because in Korea, education

became the mantra for the country. "Would you buy a Korean TV 15 years ago?" he asked. "Probably not. Today I buy a Samsung instead of a Sony. That's what education can do."

Today, he said, education in the EU and the United States were lagging. "There is an old saying: if you tell them, they will forget; if you show them, they will remember; if you involve them, they will understand. We need to change education in that way." He said that he chaired the European section of the World Economic Forum on Education, and was very interested in the results of PISA, which measures 15- and 16-year-old students' skills in mathematics, science, and reading. "The results show you pretty much what you will get in the economy and innovation 7 to 10 years later," he said. New champions were emerging. Usually PISA is won by the Finns, he said, because their educational system is so good, or by the Koreans. Last year, however, "students from Shanghai beat both groups by thirty points in every category. That is equivalent to about one year's advantage in reading, mathematics and science."

Not only STEM skills, but also 'Soft' Skills

The development of new skills in mathematics, science, and logic would be needed to drive an innovation economy, but not sufficient. The best computers today are beating the best chess players. "That's why I say we need STEM-plus—STEM plus soft skills, self-awareness, creativity, innovation." He returned to the example of Finland, which established two years ago an "Auto University," or Innovation University, where students study not only technology and economics, but also art. "This is a broad concept, and they've got excellent results. They are trying to recreate a startup mentality."

Dr. Muehlfeit concluded by underlining the need for better life-long learning programs. He described some joint research between Microsoft and the International Data Corporation; one conclusion was that in five years, 90 percent of all jobs will require at least basic electronic skills. Today, he said, 40 percent of the European population still lacks e-skills. "We need to continue lifelong learning. I'll illustrate what is wrong. When kids are in kindergarten in Europe, 90 percent of them would like to be innovators and entrepreneurs, would like to do something out of the comfort zone. By the time they leave university, only 17 percent feel that way, and only 4 percent will actually do it. That's because the old system, which is based on logic and memorizing, is not unlocking human potential.

"Imagine a system where through technology you will be able to learn in your own individual style. Today the base of the educational system is grounded in the industrial era, when we decided the factory is a good model for education. The factory is a place where everyone is told what to do."

Dr. Muehlfeit ended by challenging his audience to unlock the creativity and innovation of students and adults alike. "Now we know that everybody learns in their own way, and that's what technology through e-learning can deliver. Research by Gallup says that 80 percent of all job holders

are just doing their work for the money—not because they like it. Imagine being able to unlock those human talents and strengths. In my view that's what we need to do. In Europe we spend a lot of time discussing universities, but I think we need to reform the whole educational outlook, beginning with primary and secondary grades, in the same way."

DISCUSSION

Dr. Wessner asked whether the panelists through that Germany would succeed in attracting more students and professors from abroad.

Dr. Muehlfeit agreed that Germany should think harder about "smart" immigration to attract European professors back. He cited Canada, where more than 40 percent of people have a university degree, as an example of a country doing an excellent job of smart immigration, and rising higher in innovation indexes. In EU universities, he said, only 2.6 percent of students were non-European students. "The mix of cultures and the drive for innovation are missing here—while more than 50 percent of students in the United States are non-Europeans." Another data point he offered was that 80 percent of all software startups in Silicon Valley during the last 10 years were led by first- or second-generation Chinese or Indians.

Dr. Zimmermann returned to the topic of immigration policies, saying that in principal, anyone in the world with a university degree and a job offer could come to Germany to work. But he acknowledged that this situation might not be widely known, or believed. Whatever the reason, he said, "nobody is doing it; a few hundred are coming worldwide. So Germany has the standing of a fortress, a country that does not want to attract high-skilled labor." Only people with lower skills come for work. To attract the others, he said, a perceptual problem must be overcome. "Really, there's nothing to fear from high-skilled migrants, because they only increase efficiency and create innovations; they are also good for equality. It's proven that the more high-skilled people come into the country, the more equal the society will become." As a useful goal, he advocated a special passport for high-skilled migrants, and welcoming them. "We should leave it to the people themselves to decide where to work, and not to governments."

Dr. Collier, the moderator, noted that competition for skill scientists, innovators, and educators might look very different in coming years. At the beginning of the 20th century, he pointed out, when someone said typewriter, they were probably talking about a job description—a human who typed. Irving Fisher, at beginning of his book, *On the Making of Index Numbers*, thanked his computer, and then named the man who was his computer. "Educator and innovator still have human faces," he said, "but as we heard in the case of e-learning, 'educator' might soon become an electronic machine. Perhaps the innovator will still have a human face."

Panel IV

Growing Universities for the 21st Century

Moderator:
Reinhard Grunwald
Director
Zentrum für Wissenschaftsmanagement e.V. Speyer (ZWM)

Dr. Grunwald introduced Panel IV by noting the great range of university missions in German and the United States, and their varied roles in contributing to innovation. Some universities were seeking to improve along traditional lines of research and education, while others would present new models of partnership with both the community and the private sector. "We are expecting," he said, "some insights from at least two worlds into how to do innovation, and the contributions the universities can make. Universities can always be reformed," he added, "but today let us hear about their actual status."

CHALLENGES AND CHANGES FOR GERMAN RESEARCH INSTITUTIONS

Karl Ulrich Mayer
President, Leibniz Association

Dr. Mayer said that he had spent many years on both sides of the Atlantic, most recently returning from seven years as chair of the Department of Sociology at Yale University. In the 1990s he had spent six years as a member and co-chair of the German Council of Science and Humanities. At the end of that term, he wrote a paper titled "Perilous Past Dependency," a pessimistic view of the future science system of Germany. He said that today he would "have another look" at that topic, beginning with several conclusions.

His first conclusion, Dr. Mayer said, was that the German research system—specifically the public research system—had evolved under certain federal constraints, and its institutional form could be understood only in that context.

Second, apart from "this very peculiar historical development," the science system actually functions very well "as a differentiated field between

different institutions, with a clear division of labor, different mandates, varying degrees of autonomy and state control, varying degrees of bottom-up and top-down approaches to science, distinctive types of research organizations, and partly overlapping and partly different areas of research." He noted that the system was often "pilloried," but said he would "present it as a very functional kind of productive system."

A 'Jump-start' for German Public Science

In recent years, Dr. Mayer said, the German public science system had experienced a "veritable jump-start" in regard to the resources allocated, level of competitiveness, increased national and international cooperation, and measured outputs. Three things responsible for this renewal were major topics for the workshop: the Excellence Initiative defined by Prof. Pinkwart, the contract for research and innovation, and the European Research Council. He suggested that these measures were "segregated and not functioning well together."

His final thesis was that the challenges to the science system arise mainly from two sources. The first "has to do with the balance of financing the tech space between the states and the federal government." The other source is the very successes of the system itself—the "downsides or unintended consequences of some very positive developments."

Dr. Mayer said he would begin with a "three-minute history of the German science system." It essentially began in 1810, with the creation of the German model of the research university—the "very model that was taken over by Johns Hopkins University" in the United States. He referred to a question asked in a recent book on the American university by Jonathan R. Cole, provost of Columbia University: what is its base, and what can explain its success? In his answer, Cole described the value of the German model in terms of its unity of instruction and research.[24]

In 1911, as part of the 100th birthday commemoration of that event, the Kaiser Wilhelm Society for the Advancement of Science was established.[25] This, he said, was the first large research organization outside the university and was launched primarily by private and commercial interests. In 1946, it was the Allied powers that set the path for the later development of what became the research system in Germany today, decreeing no central German government should be in charge of education and higher education. By formalizing this mandate into the constitution, he said, "we have an institutional structure and structural financing that explains a lot which happened later."

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[24]Jonathan R. Cole, "The Great American University: Its Rise to Preeminence, Its Indispensible National Role, Why It Must Be Protected," *Public Affairs*, 2010.

[25]The Kaiser Wilhelm Society was an umbrella organization for many institutions, testing stations, and research units. After World War II its functions were taken over by the Max Planck Society.

In 1947, the German states agreed to share some of the research financing and other responsibility jointly, and they were joined by the federal government in 1949. This mutual responsibility for research was institutionalized in 1969 by a constitutional change, article 91-B, which allowed the federal government and the states together to support scientific research in institutions outside the universities. Finally, the Unification Treaty of 1990 (Article 38), mandated that all academy of science research institutes should be evaluated by a body of German scientists. A major product of this evaluation, which reduced by about 2/3 the personnel in most institutions, was the Leibniz Association. The Association took over 37 of these institutions, which joined with 40 other institutions in West Germany into the current German research system.

A Research System Distinct from the Universities

Dr. Mayer said that this resulting German research system, distinct from the universities, is now well differentiated into several large programs, each with its own mandate. They include:

- The Max Planck Society, with which he said he had worked for more than 20 years. Each Society institute is directed by a single great scholar who is given virtually complete autonomy.
- The Fraunhofer Institutes focus primarily on industrial research and receive both industry and government funding.
- The Helmholtz Association manages a community of 18 large research laboratories that are similar in some ways to the U.S. national laboratories of the Department of Energy, each focused on a long-term "grand challenge."
- The Leibniz Association consists of 87 institutions that conduct application-oriented basic research and provide scientific infrastructure.

He elaborated on the Leibniz model, which he called "a kind of a hybrid of research, where we combine basic research, applied research, research infrastructures, and the big research museums. We enjoy a large degree of autonomy in choosing programs, always with the goal of contributing to economic, ecological, and social problems."

Dr. Mayer gave a broad comparison of the German and U.S. research and education universe. The population of the United States is about four times larger, the GNP per capita of Germany is slightly smaller, R&D spending is about the same, and Germany "does slightly better" in research personnel. For institutions of higher learning, "we could have a long debate," he said, with about 250 research universities in the United States and 105 in Germany. While this number is proportionately higher in Germany, relative to population, the German universities lag far behind in international rankings. "One reason for

this," he said, "is that the big research associations are not part of these rankings."

He said he would challenge some aspects of the comparison of university graduates presented by his colleague Klaus Zimmermann. "Very clearly the proportion of a cohort entering any institution of higher learning is about 2/3 in the United States and about 40 percent in Germany. However, for the proportion finishing four-year colleges, the picture is different. And if you actually compare the proportion of the cohort that completes MA and diploma programs, then Germany looks much better."

Dr. Mayer said that the doctoral picture in Germany looks better. "There might be some debate over the meaning of recent data," he said, "but overall I would claim this is a significant and positive difference." He added that this "provocative" statement, or any comparison in terms of overall human capital, "is totally misleading if you do not include apprenticeships." The proportion of people in Germany entering the labor market with a highly qualified vocational or professional degree is about 80 percent. He estimated that "at least 50 percent of four-year college degrees are not up to the cognitive standards which are imposed by apprenticeship exams after three and a half years. So if you take these together, I think there's no doubt that overall human capital in Germany is much to our advantage."

Funding the Public Research System

Dr. Mayer turned to the support and funding of the research system. About 10 billion Euros go into higher education, he said, and about two billion Euros go into the German National Science Foundation, a doubling over the last decade. The large laboratory programs consume about three billion Euros per year, with the Helmholtz, Leibniz, and Fraunhofer programs each receiving around 1.5 billion.

In terms of funding and share of funding, he noted a mixture of top-down and bottom-up strategies. Some 90 percent of the funding for the Helmholtz Association is provided by the federal government, which is accompanied by "a very top-down approach in terms of program research." The Max Planck Society is funded in equal proportion by the state and federal governments. "This, in turn, having 17 masters for 17 institutes, insures a very high degree of autonomy." The Leibniz Association is funded by a 50/50 state-federal partnership as well." He said that all these association would receive a 5 percent increase for the next five years; the Max Planck Society planned to invest exclusively in new institutes.

Dr. Mayer reviewed the differences among how the programs make decisions. The Leibniz institutes are totally independent, legally and financially, but they have a close relationship with the resident states, and this can lead to different types of innovation. University institutes found to be innovative can sometimes develop into a full-fledged Leibniz institute, and Liebniz scientists often hold joint professorships in universities. The Helmholtz program innovates

from the top down. Max Planck innovates independently without outside influence. The Fraunhofer program, with 1/3 of its funding public and 2/3 private, follows the innovation needs of industry.

He turned to events of the past decade within this "fairly well-balanced system" of programs "with different mandates, different modes of research, and different sizes." He said that the "jump-start" had begun with a publication of the National Science Council in 2000. This publication advocated more internationalization, stronger research, greater competitiveness, increased mobility, and increased investment by federal, states, and industry. He said that he had had low expectations for this strategy, but that "what happened in the last 10 years is that the universities just turned around. Ten years ago, if anybody had told me that German professors would spend their three-month summer vacations meeting to develop cooperative plans for research collaborations, I would have said they were crazy. But this is exactly what has happened."

Introducing the Concept of Competition

First, Dr. Mayer said, the Excellence Initiative brought differentiation and inequality into the system. It brought a high degree—"some people say too much"—of competition. And the contract for research innovation has invested 5 percent increases for the next five years. "This was the response of our government at a time of financial crisis when the budget of all the departments and ministries were being cut."

What is the outcome? he asked. "If you look at the outcome, there's no doubt that it has worked. The number of publications in Germany has doubled over the last 10 to 20 years." And in Europe, Germany has consistently increased its university rankings over the past three years, according to the European Research Council

The same applies, he said, when comparing the different research associations and calculating the number of published pages and the number of publications. In a recent paper on innovation performance in the European Union, Germany was exceeded only by "the fairly small Scandinavian countries," which recurs "in a number of indicators of innovation performance. In addition, the number of spinoffs has increased in all the associations, he said. The 87 institutes of the Leibniz Association have generated more than 100 spinoffs within the last year, even though 40 percent of the institutes work in the humanities and social sciences.

Dr. Mayer saw two kinds of challenges. First, the federal states are weakened by low tax revenues during the recession; they are also slow to set clear priorities for higher education. "That means the whole initiative is falling to the federal government. If programs have to be funded jointly, the states are in danger of not being able to carry the load. The big question then is will there be a further increase in the role of the federal government in financing universities along the lines of this model."

A positive development, he said, is much closer cooperation between the research organizations and the universities. One reason for that is that only the top universities can compete for the funds. Also, the number of joint professorships between institutes and universities are "skyrocketing." In the DIW, one of the Leibniz Institutes, only one director previously held a joint professorship; today there are between 15 and 20. Finally, there is much more competition between the research organizations. "We actually compete formally within the contract, using a number of indicators on which we are compared in a yearly report."

Dr. Mayer concluded with a comment on innovation. He said that while all the research associations have been more successful in recent years in their technology transfer, there is ambivalence in Europe about this. A current restructuring of the research programs of the European Union includes a shift of support toward innovation and technology, and away from more fundamental research. "That of course presumes an idea about the production and use of knowledge by the old pipeline theory, where you start with basic research and go to applied research and then marketable goods. I very much doubt whether this theory still applies, and therefore I have doubts that the European research policy is correct in not investing enough in basic research."

GROWING THE NEW AKRON UNIVERSITY

Luis Proenza
President
The University of Akron

Dr. Proenza said that Professor Mayer's story "could in many ways be told about the United States," and that he would describe a story about one university that had many of the same challenges "in a highly competitive environment." The University of Akron, he said, was a small research university, "certainly toward the bottom of those 250 research universities Prof. Mayer mentioned," and it realized it had to work in new ways in order to compete.

"Before I tell you how," he began, "I want to share two pieces of context." The first was that universities today are being asked to play a different role as the economy has become a knowledge economy. "Largely, we've tended to think of universities as producing human capital and some new knowledge. But in fact they generate many kinds of capital: creative capital, knowledge capital, human capital, social capital, financial capital, and natural capital in many ways." In short, he said, their "product portfolio" is much broader than we have tended to think. In addition, universities have always had natural roles as conveners, bringing people together from all parts of their communities, and as developers, reflecting their substantial real estate presence.

A University Model Based on Relevance, Connectivity, and Productivity

Dr. Proenza said that the University of Akron had developed a model that is based on three principles: relevance, connectivity, and productivity. He noted that many people have a low opinion of the professoriate, joking that "something is academic when it has no relevance." He suggested that universities do indeed have to become more relevant, so that the value of their activities can be seen more clearly by the larger community. This can be done, he said, by engaging more interdisciplinary teams, communicating more effectively with the community, and focusing on real-world problems.

"We at Akron are fortunate in that we grew up over the last 140 years with the rubber and polymer industry, and developed very close ties with the larger economy. Now I believe that we need to be much more productive it the broad sense." He said that in the United States, most metrics behind university rankings are input measures that are not related to productivity or output. "If you attract very good students, you don't have to show that you add any value to them; you simply sit back and watch them develop. And if you're a large research university with lots of money, you're somehow judged to be better, even though your output per dollar may be much smaller than others. So we need some new metrics for that process."

The model Akron has developed, he explained, is to engage with its community, and to understand that if the community is not successful, neither is the university. "It's a cooperative model between our campus and the community, with lots of feedback."

Dr. Proenza said that the image of a "world that is flat" was not accurate in his experience—that economies are uneven and "spiky." "If you look at economic activity, it tends to 'spike' in these regions of high activity, and that tends to be near universities. Thousands of institutions containing specialists can add huge value to the economy." He showed a satellite picture of Germany, taken at night, revealing that the concentration of economic activity and talent is quite different from features of geopolitical maps. "All the major concentrations or pieces of your economy," he said, "are much larger than the individual cities they contain."

The University as a Broad-based, Robust Platform

In the context of relevance, connectivity, and productivity, he said, he considers the University of Akron as a broad-based and robust platform for connecting itself to the economy and the community. This platform began its initiatives with a sense of urgency. The university is within the city of Akron, so that about 1/3 of the students wanted to live within the city and the convenient vicinity. And yet that neighborhood was both unattractive and unsafe. "If you were a parent," he said, "you wouldn't want your son or daughter to live there."

Enrollments were diminishing, and the governing board concluded that it had to improve the physical facilities of the campus.

Dr. Proenza and his board began the first two initiatives, a New Landscape for Learning, a campus enhancement initiative, and University Park, an initiative to revitalize the neighborhood around the university. The university sought the help of a major Ohio-based foundation, the Knight Foundation, which responded with a $12.5 million donation to be used over 11 years. The New Landscape for Learning has resulted in 20 new buildings, including a 30,000-seat athletic stadium and two residence halls, 18 major additions and renovations, 34 acres of new green space, 30,000+ trees and other plantings, and new walkways, plazas, terraces, and gardens.

The University Park initiative, too, has been largely successful. Through both private investment and community engagement, it has prompted some $52 million in civic investments, and more than $300 million in private investments. These investments have resulted in benefits to 15,500 residents, about half of whom are students, and 300+ businesses with 24,000 employees, including 920 new jobs.

A New Orientation for Traditional Skills

The university also found itself in a fortunate position with respect to its academic programs. Akron had long had one of the strongest polymer programs in the world, a legacy of an earlier industrial era when the region was a world center of tire design and manufacture. The university realized that its skills in physical sciences, chemistry, and polymers could be reoriented toward biomedical applications. It invited four partners, including the medical school and three hospitals, to form the Austen BioInnovation Institute. Again it sought the support of the Knight Foundation, which provided another multi-year catalytic grant of $20 million. The institute was then able to leverage this grant into a total of $200M to create "the world's leading biomaterials, orthopedic, and wound healing entity," as Dr. Proenza described it.

The university has also partnered with "other atypical entities," Dr. Proenza said. "It's almost anathema for a research university to collaborate with a community college, but we did so—with two of them—and initiated a series of initiatives." One is called Operational Excellence, by which the UA and the colleges formed a voluntary partnership with three main goals: to increase educational efficiency by sharing services (such as IT); promoting all phase of job growth, from discovery of knowledge to application; and lowering the cost and time of degrees through more efficient learning pathways.

Another innovative initiative has grown out of the term "Rust Belt." The UA responded to a request by a trade organization to support more research on corrosion. The university went to the Department of Defense, which agreed on the importance of the topic and lent its own support in creating the first bachelor's degree exclusively dedicated to corrosion engineering and funded a national corrosion research center.

In another surprising direction, the UA has also collaborated with Inventors Hall of Fame, based in Alexandria, Virginia, to create a series of educational programs for high school students in STEM subjects. The program introduces well-known people who have been inducted, giving students a first-hand exposure to innovative thinking.

The University of Akron Research Foundation (UARF) is a fundamental piece of the UA strategy, a boundary spanning organization designed to link the university and industry. It has grown to $16 million in assets, provided contract services worth about $20 million, manages about 430 patents worldwide, and has initiated five joint ventures. With a research portfolio of less than $100 million, it has started more than 50 companies and 115 industry-sponsored research projects.

Growing Strength from 'Weak' Assets

Dr. Proenza explained why the UA approach is significant. In technology transfer, he said, most institutions focus on two objectives: traditional licensing of IP, and supporting the occasional startup. The UARF has instead assembled a much more diverse "tool chest" for economic development, beginning with an inventory of all the assets of the region, many of them unused, and converting these "weak" assets in ways that create strengths. These assets included outdated libraries, space, instrumentation, people, and people's patents. It also began to work with companies in new ways—"borrowing" unused IP, for example, and helping commercialize companies from other people's technology. It created an Akron Innovation Campus that, separate from the university, purchased three buildings and started a series of programs staffed by a group of senior fellows and retired volunteer executives with many skills and a will to help. This group has developed networks to bring business and academic people together; started an angel network to fund small startups; started a women's angel network and a student venture fund; and served the technology transfer needs of small firms.

In conclusion, Dr. Proenza said, "it's a question of looking at the university not as a one- or two-product institution, but as a broad-based platform that can be both flexible and robust. We have found the value of organizing 'guerilla' or under-used entrepreneurial talent, identifying uncommon partners, partnering with the city and community, coordinating closely with other regional groups, and expanding the concept of the university. We have learned the lesson that if you do those things, your institution will be successful in the long term."

GERMAN UNIVERSITIES AND THE ROLE OF THE EXCELLENCE INITIATIVE

Andreas Pinkwart
Dean, Leipzig Graduate School of Management (Handelshochschule Leipzig)

Dr. Pinkwart said that Excellence Initiative had emerged after several months of political discussion in 2005. In June of that year, the federal and state governments of Germany decided to pool extra resources in a new research initiative. Called the Excellence Initiative, it was run jointly by the German Research Foundation and the German Council of Science and Humanities. Two stages of the program have been finished, with the third scheduled to end in 2012. "My opinion," he said, "is that this is an excellent moment to give a preliminary report on this initiative." He said he would organize his report under five questions.

1. Why Set up an Excellence Initiative?

In brief, he said, it was inspired by new challenges in the globalized world, which called for new ways to promote high-level research. He noted the comment of Jamed Salmi, coordinator of tertiary education at the World Bank, that economic growth and global competitiveness are today increasingly driven by knowledge, and that universities have a natural role to play in providing that knowledge.

One strategy recommended by Salmi is to "pick winners"—in the sense of focusing public resources on a small group of successful universities. The German Excellence Initiative follows this strategy in giving a few German universities a chance to close the gap with the best research universities world-wide. This strategy, he said, represents a dramatic change for the German science system, in which public financial support for science is commonly spread among every university. Focusing on just a small group could be interpreted as leaving the majority behind, and would have been unthinkable just a few years ago. Yet the federal and state governments now recognized that a new approach was needed if Germany is to be competitive in the brain race against the rest of the world.

2. What are the Goals of the Initiative?

The Excellence Initiative seeks to promote cutting-edge research by creating outstanding conditions at the universities. The results should enhance the international image and visibility of German research universities, he said, and improve their international rankings. Increasing third-party funds and high appointments of scientists with excellent international reputation were parallel aims of the initiative. "These were ambitious goals indeed," he noted.

3. How was the Concept Implemented?

Supporting an elite within the scientific community signified a serious departure from Germany's basic tenet of equal distribution of resources. Another revolutionary change was to hold a competition among the universities. The initiative had to apply for financial support, and then face up to the universities not included.

Three lines of funding were offered. First, 39 graduate research schools were selected and given an average of 1 million Euros per year. The objective was to give leading young doctoral students a chance to improve their careers through a network of young academics and experienced scientists. This support presented young scientists with an attractive alternative to moving abroad for graduate study.

Through the second line of funding, the Initiative supported 37 clusters of excellence, with average funding of 6.5 million Euros per year over five years. The clusters attempted to concentrate and focus the research potential of German universities so as to increase international visibility of one particular aspect of their research. This approach encouraged universities to concentrate on auspicious, forward-looking priorities within their research activities and connected them to industrial partners and non-university researchers. Systematic scientific networking abroad further broadened the horizons of researchers.

The third line of funding drew the most attention. Nine universities were given up to 13.5 million Euros per year to improve their international competitiveness. German media soon called them the "elite universities." This label was not chosen by the government or any scientific organization, but it became popular and considered honorable as a recognition of scientific excellence. Universities in all three categories had to present a long-term strategy on how they would compete with universities of the international top flight.

Even the most daring expectations of politicians and scientists, including those of the DIW and the German Council of Science and Humanities, were exceeded by the number and quality of research concepts put forth in these competitions, he said. "The first round of the Initiative, in 2005 and 2006, shook up the German science system, as did the second round in 2006 and 2007. Selection of the winners from among the 600+ proposals proved extremely difficult for the reviewers, most of whom were from outside. They then consulted with political representatives. Often enough the sole difference was between very good and even better. At the end of the two rounds, science and politics together selected 85 concepts."

In summary, Dr. Pinkwart said that 39 graduate schools were selected to train top-flight researchers; 37 clusters of excellence were supported; and nine universities were selected for plans to improve universities' international competitiveness. "Germany's universities submitted a wealth of forward-looking research concepts," he said, "extending across all areas of science and all the country's regions. This not only showed their creativity, but also demonstrated

that universities, which had often been seen as inflexible, actually do have an innovative side."

4. What were the Results?

After the relatively short period of three years, the first results were clear from an assessment, published in November 2008. The Excellence Initiative, by spending almost 2 billion Euros during the first two rounds, had "created research-friendly structures and promoted interdisciplinary cooperation within universities, between different universities, and between universities, non-university research institutions, and the private sector." Already existing strengths were being improved to attract both young scholars of promise and leading, already-established researchers.

The initiative was found to be especially beneficial for young scientists, in promoting equal opportunities for male and female scientists, and in helping "balance work and family life. Not least, the initiative has made important contributions to the internationalization of German universities, and increased their attractiveness to students and scientists from Germany and abroad." Approximately 4,000 young scientists and 300 professors had been recruited in the final project, about 25 percent of them from other countries.

In the coming years, Dr. Pinkwart said, the winning institutions are likely to improve their ability to compete for the best scientists and students, thanks to new funds. The selection processes will filter out the best-performing students and perhaps achieve a goal of reducing the number of university places. Unless political changes block the process, it will be possible for the universities to establish exclusive courses for very small numbers of talented students. "The Excellence Initiative is not only changing the German science and research system," he said. "It's actually driving the country as a whole forward."

5. What of the Future?

Even during the financial and economic crisis of 2009, he said, federal and state governments decided to start the third round of the Initiative, increasing financial support. The applications for this round are being reviewed, and the winners will be announced in June 2012. The program is scheduled to continue until the end of 2017, with 2.7 billion Euros of financial support reserved for the successful universities. With few modifications, the structure of the program, with its three funding lines, will remain the same.

Given the success of the Excellence Initiative, Dr. Pinkwart concluded, "it is hard to imagine that this remarkable program will not be continued in some form. In my opinion, there should be further competitions between the universities that have been supported and those trying to reach this goal. I'm sure this kind of competition is a keystone for the advancement of the whole German science system."

DISCUSSION

Bruce Greenwood, of the European Office of the State of Massachusetts, asked who in Germany helps move innovations and new products to market. Dr. Mayer commented that one of the biggest issues being debated in Europe is the patent system. For many years the issue had stalled, he said, but now seems "moving in the right direction." The question of whether or not to patent an invention is often an open debate. If a firm really wants a product, he said, they may not bother with buying its patent from an institute. "They just come in with a big crew of lawyers and get the property they want. In terms of revenue, there are a lot of patents being awarded, but the revenue is not impressive."

Dr. Singerman asked Prof. Mayer how public investments in S&T should be measured in Germany, and whether he was feeling pressure from funders to justify the extraordinary growth in support. Prof. Mayer replied that each institute had a program budget, and had to define its goals, with indicators; these must be verified both by the board of scientific advisors and supervisory board. Nonetheless, he said, there is a debate, notably in the Leibnitz Association, about the downsides of this exercise. "It is clear that the combination of these indicators, program budgets, and peer review is needed." He said he served for many years on the board of scientific advisors of the DIW, and supported the use of peer review. "But I think institutes use constructive ways of measuring," he said, "and being accountable for output." The research organizations, too, issue a yearly monitoring report on the program for research innovation, using indicators that compare outcomes irrespective of available resources. He said there is also "an interesting, ongoing debate on what these indicators mean."

Dr. Pinkwart added that success "depends on what you want to measure." For the Excellence Initiative, he said, it is important to see that German universities are more competitive in the world. "It's not okay that German universities will rank starting at number 50 or 60 in the world. So we can now say that, according to the third European Union Report on Science and Technology Indicators, four of our universities of excellence are in top 10 in Europe, with the Technical University of Munich in third place, Freiburg University in sixth place, tied with Karlsruhe, and Heidelberg in ninth place. "That's important," he said; "you have to be visible to attract the best talent in the world, professors as well as students. And I think our excellence competition was very important in making our institutions more visible."

Roundtable

Competition and Cooperation: Systematic Challenges

Chair:
Peter Engardio
Senior Writer, BusinessWeek (retired)

Mr. Engardio introduced the roundtable by reporting to his German hosts that there was a great deal of interest in Germany on the part of Americans, "a kind of 'Germany envy.' Everybody marvels at how Germany can continue to be such a productive industrial power and exporter, given a higher cost base than the United States. He recalled an issue of *BusinessWeek* magazine that called Germany "Japan on the Rhine" in 2003—which was not then taken as a compliment. As a result, he said, many U.S. scholars are studying how Germany's innovation systems function, and how the United States might do better. Germany's heavy emphasis in innovation strategy is to promote areas where the country seems weak, such as entrepreneurism, transferring university research to the private sector, and public-private partnerships.

He then recalled that when Dr. Beyer spoke to the STEP Board in November 2010, he had noted one difference between the U.S. and German economies. That is, the United States is a highly entrepreneurial economy, while Germany emphasizes solid, steady progress. He asked whether this model would continue to serve Germany well in the coming decade, and also asked what the panel saw as their main innovation challenges.

SOME INNOVATION CHALLENGES FOR GERMANY

Dr. Beyer said that the situation today is somewhat more favorable for Germany than it had been the previous fall. He saw "quite a solid boom in the economy, with a lot of companies technologically competitive, especially the larger companies." He said that some sectors of the labor market seemed to have reached full employment. He did see several challenges. First, "it is not self-evident that you can continue the huge increases in financing research and education in the public sector. This is a huge political task." Second, it is uncertain how disruptive change, such as cloud computing, might transform

companies for better or ill. Third, Germany will see demographic change accelerate around the end of this decade. Fourth, it will be "a huge challenge to make Germany attractive to the brightest talent." And last, the energy sector must be reoriented toward control of emissions, with costs that are competitive for industry while the atomic energy sector is reduced.

Mr. Engardio asked Mr. Curran whether he would start a new company in Germany or the United States. Mr. Curran said it would depend heavily on the type of company. He had started five companies, four in Germany and one in the United States. One was successful, and the others were "okay." The success had less to do with which country it was in, he said, than the "good and fertile environment" of the location—in that case, near MIT in Massachusetts where the company, Component Software, was founded. "We were looking for people who were able to design a certain type of software, and at the time we would have had trouble finding those people in Germany. Also, given the culture, we would have had trouble convincing them to leave large organizations to join a startup. On the other hand, Germany is a very process oriented culture and economy, and if I wanted to design software for the automobile industry, I would consider doing it in Germany, where you have the engineering expertise and customers. In general, it's more difficult in Germany to approach a large organization with a new innovation than it is in the United States."

Mr. Engardio asked whether Germany is developing a more competitive entrepreneurial ecosystem for new tech companies, or whether the United States is still the primary magnet? Mr. Curran said that in the United States 100 years ago, entrepreneurs and industrialists were regarded as heroes, and they were the first "globalizers of industrial thinking." In the 1960s through 1980s, the United States continued to have many successful entrepreneurs, a tremendous belief in change, and a market eager for it. "In the late 1970s, Bill Gates would hawk his Altair computers at university fairs. There was a belief that something was going to happen that was larger and more important than going to work for a large organization. A respect for risk taking was in the culture."

"The first company I started," he continued, "was in Berlin. I was 24 at the time, sort of stuck here, and I decided to start a company to make money. I had to go twice to the German better business bureau for interviews on whether I was qualified to start a business. It seemed strange, coming from the United States where I was recognized at the university for certain software skills. It seemed like a way to protect the rest of the culture and industry against entrepreneurs instead of encouraging them.

THE IMPORTANCE OF AN ENTREPRENEURIAL CLIMATE

"I'm very involved in venture capital and innovation," he went on. "There has been a lot of change since I first came here, but even today, I think Germans still don't have the same cultural and social motivations to be entrepreneurs. When I started at SAP, the company was seen as an

entrepreneurial organization, but it was already 20 years old. It didn't have the entrepreneurial flair it could have had in the United States. Today there are few companies in Germany to be partners with young software entrepreneurs or high-tech entrepreneurs, and despite the structural innovation going on, which is positive, there is still lack of talent and experience that would make it more comfortable for an entrepreneur to start here."

Mr. Engardio asked Dr. Beyer how important it was for Germany to have a more entrepreneurial climate, and how much it could be improved through policy. Mr. Beyer replied that it was "extremely important," and that many people at all political levels were discussing the issue and working to improve it. There are now entrepreneurship programs in universities, for example, and "a lot of money is spent there." Nearly every university had offerings in this area for students, he noted, "but it's a question of the culture. It is also the question of giving people a second opportunity. Bankruptcy laws have recently been changed to give people another chance when they have failed as entrepreneurs. I would argue that we are moving forward—hard."

Mr. Engardio then asked what lessons Germany offers the United States.

Mr. Dahlman answered that Germany has a "more developed process for taking knowledge into action." The United States has focused more on breakthrough innovations, and hasn't been as systematic about moving them to the market. "I'm most impressed by what we just heard about the changes in the education system in Germany, in particular the Excellence Initiative. I am most interested in how well that is doing, and the research metrics that are used for institutes that are very different from one another."

Mr. Wolff said that Germany's emphasis on human capital is very impressive, as is the willingness to reexamine the education system with the understanding "that we live in a world of competition and that educational institutions have to compete." This is true not only in Germany, he said, but across Europe and internationally. There has to be a metric to measure the universities' contribution to society.

Dr. Wessner said he was impressed by the diversity of opinions, including the view that EU policy should not support applied research, and the contrasting view in favor of the research supported by the Excellence Initiative. He also noted the strength of technical and vocational education in Germany. "The quality of educating the work force seems far superior here," he said. "This is a major difference, and one that has an impact on manufacturing."

Mr. Curran said that his children had grown up in both systems. He had respect for the level and quality of vocational training in Germany. One drawback was that "there are many more vocational trainees than there are interesting positions for them," but he found this "a good challenge to have." A positive aspect, he said, was the custom of a high school graduate spending 1.5 or 2 years as a vocational trainee at a bank or large company. One of his sons had vocational training at an Internet company, where he could learn what was expected by industry, and the company could test his ability as a potential hire.

In the United States, he said, the broader education system offers many possibilities even to vocational trainees, but it creates a level of confusion for employers, who often cannot identify a student's primary vocational skill.

He also commented about excellent university initiatives in Germany, which large employers are eager to work with. But he warned of the danger of brain drain. He cited the example of India, where many of the top students from the IITs go to work elsewhere for global companies. "I think you need to be careful about equating excellence, elite, and innovation, as we seem to be doing in this room."

THE STRENGTH OF GERMAN APPRENTICESHIPS AND TECHNICAL TRAINING

Mr. Beyer affirmed that apprenticeships and technical training "is obviously one of the underpinnings of the German economy." Germany is specialized in engineering and technology, which would not be possible without such training. "That explains a lot of our success in exporting and increasing value added." Also, he said, part of the success of the Excellence Initiative is its overwhelming support by the majority of observers and people involved, despite its different approach. A point not yet discussed, he said, is the current huge inflow of young people into German universities. "Politicians are trying to cope with this, but it will stop at the end of this decade, when numbers will decrease rapidly. You have to look ahead in questions like this and prepare policy." This change, he said, would affect major features of education, including immigration, brain drain, and the inflow of bright students.

Charles Ebinger of the Brookings Institution said he was struck by Prof. Mayer's emphasis on quantitative measurements of success. In the states, he said, many evaluations are written that probably didn't need to be, which he attributed to the "publish or perish mentality. We're writing more and more about less relevant issues. Why do we not hear more about evaluating the quality of teaching and the time professors actually spend with students?"

Mr. Wolff added that in the case of China, the abundance of patents was not surprising, given the centralized political system. "When you have a command economy," he said, that promotes patenting and publishing, "you're going to get a lot of utility model patents that haven't had much review. And you'll have a lot of papers written that don't measure up." He said that such figures are not helpful as metrics, but alternative metrics are not available.

DAY 2

Panel V

Helping Small Business: Current Trends and Programs

Moderator:
David Audretsch
Director, Institute for Development Strategies
Indiana University

Dr. Audretsch, an authority on the relationships among government policy, innovation, and entrepreneurship, opened the panel by noting that small businesses play similar roles in the both United States and Germany. Most notably, small firms are credited with creating virtually all new jobs. "Both countries undertake impressive policies to promote their small firms," he said. "But what strikes most observers of small business in Germany is what's called the *Mittelstand,* the so-called hidden champions.[26] You get a sense of stable, long-term small- and medium-sized firms that don't come and go as they do in America. In the United States we have more of an entrepreneurial tradition, where the goal is to grow, and the alternative is to disappear." He welcomed the "two wonderful speakers to help us highlight both systems."

[26]The Mittelstand, or "mid-level," companies (generally considered to include both SMEs and family-owned businesses) include some 70 percent of all private-sector employees in Germany, according to the Institut für Mittelstandforschung. They are concentrated in the sectors of machine tools, auto parts, chemicals, and electrical equipment, and many are export-oriented.

THE "MITTELSTAND" PROGRAMS AND INNOVATION IN GERMANY

Rainer Jäkel
Head, Directorate for Technology and Innovation Policies
Federal Ministry of Economics and Technology (BMWi)

Dr. Jäkel said that it was a big honor to participate in this workshop, and urged his fellow participants not to forget "the 'i' at the end of BMWi, "because I hope we are as innovative and successful as the company that uses the 'i' in front of its products." He also greeted colleagues from the US federal agencies, especially the National Institute of Standards and Technology (NIST), because "a lot of what we do is closely related to what NIST is doing. One is to support SMEs, and we are also responsible for the German Metrological Institute and the Institute for Materials Research." He said he had been honored twice to visit NIST.

Dr. Jäkel offered several remarks about the strengths and weaknesses of German programs that support small and medium-sized businesses. He reiterated Mr. Schütte's observation that Germany has a high proportion of innovative and research-intensive companies, many of which are medium-sized. Of the total R&D expenditures in Germany, more than two-thirds are made by companies, with the state responsible for only a small proportion. "I think this is a sign of the strength," he said, with the result that Germany is a large exporter of technology products, ahead of the U.S. and Japan.

The more significant strength, he added, is the well-trained human capital, especially of engineers and skilled workers. Germany's economic strength is reflected by its standing as by far the largest applicant for patents at the European Patent Office. No less important, he said, is the excellent research infrastructure, with the Fraunhofer institutes playing a lead role in technology transfer. Equally significant the roles are played by the Max Planck, Helmholtz, and Leibniz Institutes. He noted that all of these strengths were confirmed by a new survey released shortly before the symposium by the American Chamber of Commerce in Germany.

Among weaknesses, Dr. Jäkel said, was that much of the country's R&D is confined to only a few sectors, notably the automotive sector, which accounts for a more than a fourth of R&D expenditures; machine construction; electrical engineering, and a few others.

On the other hand, he noted, much advanced technology developed in these industries finds its way to uses in media industries and other traditional areas; this integration of advanced technologies into traditional areas he saw as a particular strength.

A weakness that had already been described, he said, was the "substantial deficit" in start-up financing and venture capital, especially when compared to the U.S. "This is a weakness that we must do something about," he said. The education system is also underfinanced, he said, which poses a grave

potential burden for the future. This shortage of skilled workers is brought about by demographic change, which promises to become more acute.

Given these weaknesses, Dr. Jäkel said, the German government had made the courageous decision, in the midst of a financial crisis, to elevate the support for research, development, and training in its High-Tech Strategy for 2020. It decided to invest six billion Euros in R&D in the current legislative period, and six billion in the education system. "We had a large consensus from all the major parties," he said, "that our future depends on innovation, research, development, and education, and that this is not the moment to economize." He said that the investment by the private sector did not drop significantly, while the state contribution increased.

He turned to the very large number of SMEs, calling them "the backbone of industry." These have often been family businesses for three, four, five or even more generations, and he stressed that "these companies have a very long-term orientation. They are not focused on the next board meeting, or the next business cycle, but very much on the long run."

As an example, Dr. Jäkel recalled visiting one of these "hidden champions," a company located "behind the seven mountains," or in the countryside, but with close regional ties to educational and research institutions. This family firm had worked with these institutions from generation to generation, continually re-inventing itself according to new opportunities. The father and the grandfather had long made jukeboxes and cigarette machines, but now the company had upgraded its skills to become a global leader in electronic connections for urban use and also plug-in connections for wind turbines and similar facilities. The current owner is working in robotics with help from the German Institute for Artificial Intelligence. "So you can see the evolution of this company over a short time period—the company remains the same, with the same family name, but it is reinventing itself, as are many SMEs in Germany."

German innovation policy, he said, is designed to prepare the ground for the future for these companies. Most important, he said, is the economic framework, especially for SMEs that are not in a position to move their sites. Equally important is the issue of entrepreneurship in Germany, so that new companies enter the market and stimulate competition. It is also important that existing SMEs are assisted in using the research facilities of universities.

Addressing the broader concerns of SMEs, Dr. Jäkel said that taxes are always a major issue, despite a recent reduction of the corporate tax to be more competitive globally. One problem has been that German capital receives worse treatment than foreign capital within the tax system, which affects the health of the VC industry. Another drawback, he said, "is the loss of contracts, which is important particularly in biotechnology, because in Germany the use of debit carryovers is limited." He said that this situation had not yet been remedied, because "unfortunately, finance ministers think differently than innovation leaders."

An important need is a stronger infrastructure for patent rights and other intellectual property. "We are in the midst of creating a European

Community patent, and shrinking the language regime from 21 to three—namely English, German, and French. This would reduce the cost of patents for SMEs significantly." Another important issue for SMEs, he said, was the standardization of technology transfer and research processes. This issue, he said, was receiving a high priority.

SMEs also stood to benefit from some of the reforms planned for the educational system, Dr. Jäkel said. While SMEs focus on activities from the creation to the marketing of goods, the general need to strengthen R&D justifies the involvement of the state. Problems include adequate funding of R&D projects for SMEs, which banks are reluctant to underwrite. A second is that for SMEs to be sustainable, they depend to some degree on universities' research facilities. "Therefore, the central point of our policy is to strengthen cooperation between SMEs and research institutions." He noted that the Ministry of Research had opened a window specifically to connect SMEs with the high-technology trade program of the Ministry of Research.

In regard to entrepreneurship, he described a program called EXIST that encourages universities and research institutions to familiarize students with entrepreneurial thinking. The program supports students and research staff in efforts to create business plans and develop marketable processes and products.

Referring to earlier discussions about the weakness of the German private market in funding startups, Dr. Jäkel said that five or six years ago a public-private partnership between government and industry took a positive step to remedy that problem. It created a start-up fund with 240 million Euros in state funds and 32 million Euros in funds from corporate partners. The goal of the fund is to help young companies financially in their first year, with a particular focus on high-tech companies. Committees appointed by business experts and venture capitalists select promising fields to support. The program had yielded positive results, partly because the funding is managed by the recipient companies themselves. Furthermore, ever since the first round of direct financing, a number of private businesses and venture capital funds had joined the program. As a result, a second fund was planned by six German industrial companies and at least 10 partners' companies.

A small but important area for new businesses, he said, is "innovation consulting," which makes new companies aware of the importance of innovative strategies and management. A flagship program is the Central Innovation Programme Mittelstand, launched in 2009. It promotes cooperation between SMEs, and between SMEs and universities or research institutes. In addition, it supports individual project managers in specific companies that need assistance as they develop products and bring them to the marketplace.

His agency had used various partners to manage these programs, including competitively selected private service providers that specialize in assessing R&D projects. This strategy had worked well, Dr. Jäkel said, with the agencies acting and reacting flexibly to administer a large stimulus program. The maximum amounts for each SME were not large, he said, but the stimulus program had increased the amounts by 40 to 50 percent.

An important feature of the program, he said, is its bottom-up design. It is open to any field of technology and does not require fixed delivery dates. The SMEs can access their funding at any time, for any topic that is important to them. International corporations can also be supported, primarily within Europe. The program has received almost 20,000 applications in just over two years; 13,000 were approved, and the rate of applications is projected to continue at about 6,000 per year. He noted that the program was also successful in fast turn-around times. Well-structured applications can be processed and approved within two to three months, and in some cases faster.

Dr. Jäkel also emphasized the importance of cooperation in the program's success. It targets small companies of two sizes—10 to 50 employees and 50 to 250 employees—with a strong focus on engineering and production, materials, electrical equipment and instruments, and IT. In many partnerships, high-tech firms bring new abilities to traditionally low-tech industries. In textiles, for example, the company was not doing traditional low-tech production, but integrating techniques like nano-coating. In such ways, he said, the low-tech industries become higher-tech, partly through the structural aids of the program.

He added that a special feature of innovation in Germany is its communal industrial research, by which many branches of industrial sectors have, for more than 50 years, maintained research associations to monitor the particular needs of those branches. Such monitoring usually precedes competitions, and the results of the competitions are often made public. These projects are wholly run by the private sector, and the members of the monitoring committees come from SMEs. Large companies have their own loan program that provides larger amounts of funding.

In summary, Dr. Jäkel said, that a central goal of his Directorate is to strengthen the innovative capacity of German SMEs, sustain their essential role in the major industrial networks of Germany, and support their success in the global markets. "We want to encourage this mainly through incentives," he said, "ranging from entrepreneurship to total funding and research development projects. In addition, we want to strengthen the education system and face the problem of our aging population. This is a particular issue in Germany, and quite different from the U.S., which is a classic immigration country that constantly adds new, well-trained people to their human capital. As for our SMEs, however, we are in good shape, and I hope this will continue."

SMALL BUSINESS INNOVATION: FEDERAL INVESTMENTS TO CROSS THE VALLEY OF DEATH

Charles W. Wessner
Director, Technology, Innovation, and Entrepreneurship
The U.S. National Academies

Dr. Wessner opened his talk by saying that the Obama Administration had "shown great sensitivity to innovation policy," and had developed "coherent and broad-ranging policies" to address the "mega-challenges" discussed by previous speakers, including economic growth, developing sustainable energy, slowing climate change, delivering global health, and improving national security.

One theme of the meeting, he suggested, was that innovation is essential in redesigning the path forward. He described this "innovation imperative" under three headings:

- Innovation is key to addressing global challenges and strengthening a country's competitive position.
- Collaboration among private firms and universities is essential to capitalize on investments in education and research.
- New partnerships are needed to foster innovation and collaboration.

Competition in the 21st century is based on innovation, he continued. In terms of policy, the key challenges in sustaining innovation are to fortify national R&D budgets, create a positive environment for innovation, support high-tech innovation clusters, and use innovation awards to "provide oxygen" for the process itself.[27]

Innovation was a central motivation in formulating the "Lisbon agenda" of the European Union, in which European leaders pledged to invest 3 percent of each nation's GDP in research and development. Since then there has been some progress in the EU and the United States, but total R&D spending by leading nations in East Asia have collectively passed Europe in 2003, and is approaching that of the United States.[28]

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[27]Innovation is often linked with invention as part of the creative process. While invention may refer to a new product or idea, innovation is the use or commercialization of the invention. More detailed is the definition of Joseph Schumpeter: "The introduction of new goods (…), new methods of production (…), the opening of new markets (…), the conquest of new sources of supply (…) and the carrying out of a new organization of any industry." A simpler version is that of the American Heritage Dictionary: "The act of introducing something new."

[28]R&D expenditures for the United States, EU-27, and Asia-8 economies: 1996-2007, National Science Board, *Science and Engineering Indicators 2011*, Arlington, VA: National Science Foundation, 2011.

The United States does make "very substantial investments" in R&D, Dr. Wessner said. The U.S. share of global R&D in 2010 was $415 billion out of total global R&D expenditures of $1.25 trillion.[29] Japan's share was $148 billion, China's share $149 billion, and Germany's share $83 billion. In the United States, about two-thirds of R&D spending came from private sources and one-third from public sources. An overarching problem is that the federal investment in R&D as a percentage of GDP has been declining since the early 1960s. And the private sector, pressured by competition from Asia and Europe, has devoted more of its R&D spending to applied research and development.

In addition, the approximately $148 billion in federal R&D spending is skewed away from fundamental discovery. Of the defense R&D budget, which accounts for more than 50 percent of federal R&D spending about 90 percent is spent on development.[30] "We overstate what we spend on R&D, and should not be congratulating ourselves on this overall share," Dr. Wessner said. On a positive note, the federal government does invest generously in health care research, Dr. Wessner added, which has the potential to bring enormous opportunities for our well-being and productivity.

Some Risks to the Innovation System

Dr. Wessner enumerated some major risks to the U.S. innovation system. The first was complacency among many of our policymakers about the nation's competitive position in the world. There is little understanding, he said, of how hard this nation has worked to achieve its leadership position in R&D, and how much more is needed to maintain this position. A second risk is the focus on current consumption rather than investment for the future. After 12 tax cuts during the past three administrations, he said, "we are not making the investments our fathers made. This can only reduce the opportunities our children will have." Finally, there is too much emphasis on research alone and not enough on its development and commercialization. Too many promising products and prototypes "are gathering dust on the shelves of laboratories around the country" without reaching the marketplace.

At the same time, he said, the U.S. has important strengths that give reason for optimism:

- The public values science and technology, and trusts authorities to maintain high standards and safety.

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[29]Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators*, Paris: Organisation for Economic Co-operation and Development, 2008.
[30]American Association for the Advancement of Science, 2010.

- The culture places high social value on commercial success, and allows those who fail to try again. "We admire people who can create wealth out of new ideas."
- The United States has entrepreneur-friendly policies and markets that are truly open to competition. "You can enter the market with a new idea without being excluded by an oligarchy."
- A strong IP regime encourages research and the diffusion of research results.
- U.S. bankruptcy law allows a person to not only build up a company in the United States, but also to terminate it and start again if an innovation should falter. "In Europe, there is still a legacy of punishing people who fail."

Dr. Wessner cited the pioneering work of David Audretsch and others in documenting why small innovative companies are key players in bringing new technologies to market. Small businesses, he said , grow jobs, increase market competition, generate taxable wealth, create welfare-enhancing technologies, and, over time, transform the economy.[31]

At the same time, small, innovative businesses face major challenges. The first is high regulatory burdens. One recent study concluded: "In the distribution of federal regulatory costs, a disproportionately large share falls on small businesses. Very small firms (fewer than 20 employees) fare the worst, spending 45 percent more per employee than large firms to comply with federal regulations.[32] In addition, new firms struggle for adequate financing. They are often forced to depend on "friends, family, and fools," with banks hesitating to lend to small businesses.[33]

The Peril of the Funding Gap

Many people assume that small companies routinely turn to venture capital firms for support, but this is true only for those with a track record and preferably revenues. Between the stage where the individual and perhaps friends or family sustain a young company, and the stage where VC firms are interested, looms a significant gap (popularly called the "Valley of Death") that has widened over the years. Just below the level at which VC firms typically invest are angel investors (usually individuals), who may be able to provide a million or so dollars, but a VC firm will seldom take an interest in an investment of less

[31]"Between 1980 and 2005, virtually all net jobs created in the United States were created by firms that were five years old or less." Robert Litan, Kauffman Foundation, 2010.
[32]Mark Crain, "The Impact of Regulatory Costs on Small Firms," SBA: SBHQ-03-M-0522, Washington, DC: Small Business Administration, 2005.
[33]*Wall Street Journal*, "Loan Squeeze Thwarts Small-Business Revival," March 15, 2010.

than $2 to $10 million, and in return will expect a fairly rapid and substantial payback. As Dr. Wessner pointed out, "Venture capital is not an institution designed to help the poor. Its objective is to come in late, get out early, and make money for those who invest in the fund."

Unfortunately, he said, a common myth in Washington, especially in the Congress, is that if an idea for a company is a good one, the market will fund it. In reality, potential investors have less than perfect knowledge, especially about innovative ideas; this "asymmetric information" leads to suboptimal investments.[34] In addition, venture capitalists are prone to herding tendencies, prefer less risky stages of development, and allocate only about 8 percent of their funds to "seed stage" firms.

Tools to Help Avoid the 'Valley of Death'

Fortunately, Dr. Wessner said, the federal government has developed several tools to help firms avoid the Valley of Death; foremost among them is the Small Business Innovation Research (SBIR) program. The program is stable, having been in place for 25 years, and, as a set-aside mechanism, it currently allocates a steady 2.5 percent of each federal agency's R&D budget to small business awards and contracts. Total spending is about $2.5 billion a year, large enough to achieve a portfolio affect over a number of years. It is also decentralized over 11 agencies so that every agency can be an "innovation agency."

SBIR has several conceptual advantages, he said. It uses a rigorous, double-gated competition, with only about 20 percent of applicants accepted for Phase I. It is flexible enough to allow candidates to try again if they fail. Because recoupment is through the tax system, grants and contracts lower the risk faced by prospective entrepreneurs.

After nearly two decades of operation, the Congress asked the National Academies to assess the program; in turn, the Academies found SBIR to be "sound in concept and effective in practice." Some favorable aspects of the program are that loans don't have to be paid back, a company can keep its IP, and approval by SBIR achieves a "certification effect" that raises the profile of awardees as potential investments for venture capitalists. It also helps to create new companies and to support existing companies. SBIR is, in effect, an innovative procurement tool for the government and a low-cost technological probe to explore new ideas. It responds quickly to urgent national needs and diversifies the government's supplier base. University faculty don't have to give up their positions to participate, and an applicant does not need to found a

[34]George Akerlof, Michael Spence, and Joseph Stiglitz received the Nobel Prize in 2001 for their analyses of markets dependent on asymmetric information.

company to apply. It helps link universities with companies and creates new spin-outs.

"The fact that a high proportion of [SBIR] projects reach the marketplace in some form is significant, even impressive," the report concluded.[35]

Measuring the Success of the SBIR

SBIR success has been measured in many ways. It increases employment by helping new startups grow and creating high-quality jobs. It promotes innovation, as indicated by numbers of new products, patents, licenses, and publications. It helps federal agencies meet success in their missions through acquisition and procurement. As examples, NASA uses SBIR-funded lithium-ion batteries to power the Mars Rover, and DoD uses SBIR-developed armor to shield against IEDs. The SBIR certification effect can be seen through program "alumni" that are successful as public companies, including Qualcomm, ATMI, Martek, and Luna.[36]

The potential role of SBIR funding is well illustrated in the example of A123, an innovative battery company in Massachusetts. The research for A123 was done at MIT, where NSF funds had helped develop a technology based on "an advanced cathode material for lithium-ion batteries." When the inventors decided to form a company, they won an SBIR award from the Department of Energy to help develop the core technology, which has applications for computers, power tools, and hybrid-electric vehicles. Then a $250 million grant from the government led to VC funding and finally an IPO. By May 2011 the company had a market capitalization of $712.3 million.

The SBIR is sometimes criticized for "intervening" in the marketplace, said Dr. Wessner. He said that a more accurate image of SBIR is a market-oriented procurement program that creates new information for the market about the technical feasibility and commercial potential of innovations. It then draws more participants into the program, introduces new products to the market, and lets the market decide whether the innovation is worth converting into solutions for social problems.

"This is the same challenge you have in Germany, and that every country has. We would argue that the policy framework matters immensely, and that the SBIR is one proven policy tool."

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[35]National Research Council, "An Assessment of the SBIR Program," Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008.

[36]Irwin Jacobs, founder of Qualcomm, told Congress, "Getting the grants translated into stamps of approval that allowed Qualcomm to pursue other sources of private capital." Congressional Testimony, February 2011.

In conclusion, he posed several questions for his German colleagues:

- Are there programs that provide incremental early funding that allow Mittelstand companies to cross the Valley of Death?
- Which programs bring sufficient resources to reach critical mass?
- Which programs allow small firms to gain access to the public procurement process?

In closing, Dr. Wessner suggested that a common challenge for Germany and the United States was to adjust to and help shape the new globalization dynamic. "This may involve initiating change through competitive incentives and major investments. Learning and cooperation are essential for both of our countries."

DISCUSSION

Ambassador Wolff asked about the nature of the cooperation between small firms and the Fraunhofer Institutes or federal entities. "Does the government transmit technical assistance? Is the goal for the SME to become a large enterprise, and does that happen? Do they become major competitors, like Qualcomm?" He also asked whether the SBIR program provided only funding or also technical assistance.

Dr. Jäkel said that while the SBIR program is oriented toward mission needs of federal agencies, the German support is oriented to the needs of the companies. "We want to help them bridge the financing gap," he said. "Banks don't give enough money for R&D because it's too risky. We help them cooperate with Fraunhofer, and also research institutions, universities, SMEs, and others. I think it is a good model of how technology and knowledge transfer can succeed." He said that direct cooperation between an SME and a university facilitates a direct transfer of research to a company. "We want them to grow, but in the end it depends on them. If we look at hidden champions, or global SMEs, they integrate to the region even while half of their employees are abroad. Many have grown from dozens to thousands of employees."

Dr. Wessner said that in regard to SBIR, it provides no formal technical assistance, but often a program manager can offer valuable information and collect feedback. A number of agencies already provide market training. This is necessary because many of the company leaders are professors, many of whom require help in hiring someone with experience running a company. Helping companies scale up their production and grow remains difficult, and the causes are not always clear.

A questioner asked about the Manufacturing Extension Program in the United States, which helps SMEs acquire new skills, such as lean manufacturing. He asked whether Germany offers a similar service, or whether companies learn from the Fraunhofers.

Dr. Jäkel said that the answer was "both." A special program offers small SMEs various consulting services and a small grant of 15,000 Euros. The companies learn in cooperation with Fraunhofers and others how to develop their business, and how to collaborate in networks and clusters.

Dr. Prabhakar asked about the goal of the program to support SMEs. Dr. Jäkel said that it is a bottom-up program, open not only to all kinds of technologies but different strategies, with the main focus on cooperation. "That's what SMEs need. They need knowledge of research institutions, but also ability to do some R&D on their own, and they get partners for that, and also support networks. We bring together knowledge to let them be more successful in the market."

Dr. Neuhoff asked whether the SBIR program held open calls for proposals.

Dr. Wessner said the calls were not open, and can be quite specific in their goals, such as developing a new material or building certain equipment. "An advantage is that it lets people bring in their own ideas. It is abused when agencies tell companies what they want."

Dr. Jäkel added that the Center Innovation Program for SMEs had no calls at all. Instead, companies can apply as they wish, and even receive help in designing their project. About 65 to 70 percent are approved; he said that while that figure may sound high, most weak projects are already screened out beforehand by agencies.

Panel VI:

Early-Stage Finance and Entrepreneurship

Moderator:
Alexander Kritikos
Research Director
German Institute for Economic Research (DIW Berlin)

Dr. Kritikos welcome participants to the session on early stage financing and entrepreneurship. He reviewed some of the reasons it may be expensive to explore and develop innovations, including the need to pay high wages, the cost of an expensive laboratory, or the desire to patent the invention on which an innovation is based. In sharp contrast to large firms, startups usually do not have the revenues needed to underwrite such costs. Therefore, entrepreneurs who wish to be active innovators need access to risk capital. This capital is far more abundant in the United States than in Germany, he said. In 2010, German firms or individuals invested some 650 million Euros in small firms and entrepreneurs. In the United States, this figure was about $12 billion. In the year 2000, the figure for the United States reached about $100 billion, while in Germany investment in risk capital was near zero.

What are the reasons for this difference? he asked. Researchers have investigated many possibilities. In the United States, venture capital firms have existed since World War II, while in Germany the first firms were not founded until the 1980s and 1990s. "And we know that in the United States it took 35 years before venture capital became a force." Other hypotheses, he said, were that Germans are less willing to take risks than Americans; that German entrepreneurs are less likely to get a second chance from their peers, or from society; that the capital markets are larger in the United States; or that the regulatory climate in the United States is more favorable to venture capital.

"There are so many questions," he said. "I hope you will be able to answer a few of them as we hear from some of the experts in this arena."

NEW INITIATIVES IN EARLY-STAGE FINANCE IN GERMANY

Peter Terhart
Chairman
German Private Equity and Venture Capital Association (BVK)

Mr. Terhart said he would comment on several aspects of the German financial system, beginning with the statement by Dr. Kritikos that only about 0.1 percent of Germany's GDP is dedicated to venture capital. How could this be? he asked. An important reason is a condition that "fundamentally sets us apart from the United States: we do not have pension funds. This means that a very big player is omitted from the venture capital market." One reason this is so important, he said, is that a pension fund "thinks in terms of generations, in terms of long-term and stable investments," and knows that a nation must invest in its future if is to continue to develop. In Germany, pensions are for the most part paid by labor.

Another feature of the financial system needing attention, he said, was the banking sector. After World War II, the government compensated for the lack of a "financial economy" by creating a large public banking sector. These public banks were intended to finance the "real economy," including companies that needed capital for early-stage activities, growth, and expansion. During the 1950s and 1960s, he said, all sizes of companies were financed by the banks, which, in principle, had surplus funds. The scarcity of private funding for companies, such as angel investors and venture capital, had little consequence as long as the banks could fill the needs. This changed with the beginning of the current crisis, however, and banks that had had enough money for decades were no longer willing or able to provide venture capital.

A second aspect of the financial system was its long-term orientation. This has allowed sustained corporate development in the "real economy." After the war, this financing nourished the small and medium-sized businesses and "hidden champions" mentioned earlier. The real economy and the financial economy developed hand in hand, supported the number of companies that constitute today's SMEs, as well as the heavy legacy industries. Thus, innovation and the creation of new companies took place within existing companies. In other words, he said, "the reinvention of the economy was not happening by way of entrepreneurship and start-ups, but rather through incremental steps in the small and medium sector, heavy industry, and other established organizations. This lead, he said, to more conservative, step-by-step change, rather than more radical or disruptive innovation.

Third, Mr. Terhart said, the legacy of support for long-standing, successful companies influenced the career choices made by young potential entrepreneurs. A young engineer, for example, who may contemplate starting a new firm, will also be offered positions with SMEs and large firms of the existing economy. They will face a difficult choice: Should I take the risk of establishing myself independently with my own firm, or should I go to Siemens

or a successful "hidden champion" where the salary and employment are secure? The lack of venture capital and concern about the risks of entrepreneurship may often persuade a young person to make the conservative choice.

The federal government understands and wants to change this situation, he said, and knows that to do so it must provide more incentives or competitive support for those interested in entrepreneurship. Some effective programs have been implemented for this purpose, he said, and they are essential in avoiding a continuation of overly conservative behavior. Many incentive projects have received initial funding, he said, and the next step is to sustaining their funding.

Despite the lack of an established venture capital industry, Mr. Terhart said, some new projects are presenting opportunities for raising funds as well. For example, many family businesses—even though they are not included in official figures—and branches of larger companies are strongly dedicated to forming or joining venture funds to support young or beginning firms. In addition, foreign funds, such as some French funds as well as some non-European funds, show interest in investing larger amounts of money in private equity or venture capital funds. "We are seeing that, as a whole, there is a greater enthusiasm in approaching this matter in earnest," said Mr. Terhart, starting with early steps taken by the Ministry of Science and Technology and the Ministry of Economy.

"These are demonstrating today," he concluded, "a willingness to create the conditions necessary for the establishment of a venture capital industry. We see that our own equity industries are now stepping into the breach, as they have seen that the banking industry—the old players—can no longer do so."

THE CLASH OF INNOVATION CULTURES: THE UNITED STATES AND GERMANY

Eran Davidson
Managing Partner
Hasso Plattner Ventures

Mr. Davidson introduced himself as an Israeli who had making venture capital investments for 16 years, the past six of them from his current base in Berlin. Having invested in Israeli, American, and German companies in many fields of technology, he said he would present some comparisons among the investment and entrepreneurial cultures of the different countries, especially the United States and Germany.

He said he had chosen the title of his short presentation, "The Clash of Innovation Cultures," because of a peculiar situation. He said that "Germany is a funny country in many ways, especially when it comes to innovations," because it invents so much and profits from its inventions so little. He showed a chart of fundamental inventions made in Germany, including the light bulb in 1854, the telephone in 1859, the television in 1930, the maglev train in 1934, the computer

in 1941, and the MP3 in 1987. "Guess what?" he said. "For all of those technologies and more, revenues are generated by American, Japanese, and recently Chinese companies. Why is that so?"

Mr. Davidson asked his audience to imagine meeting someone who had a great idea and wanted to share it with a colleague at a start-up company. "If you go to an American guy in Silicon Valley, he'd say, 'Let's try to do it today.' If you ask the same question of a developer in Germany, he would say, 'It can't be done.'"

He also offered another set of responses to indicate how different the cultures in the two countries are. In Germany, he said, a new proposal might be greeted with the following replies: "I don't buy it. I just don't get it. How boring. I'm too busy." The same new proposal to a developer in the United States might elicit this sequence: "I don't understand it, but it sounds interesting. Tell me again. I enjoy hearing about your idea; let's do lunch and talk it over."

Different Values in the United States and Germany

Mr. Davidson said there were also different sets of values in the two cultures. In Germany, perfection is valued with an almost religious fervor. Perfection in Silicon Valley, on the other, is likely to be regarded as time-consuming and inefficient. Longevity is important in Germany, where an idea must be assigned to a long-term plan of at least 20 years. In Silicon Valley, quick wins are important. "While a culture of thinking dominates Germany," he said, "Silicon Valley has a culture of just doing."

In Germany, he went on, "we accept the way things are; we don't ask too many questions. In Silicon Valley, we want to try new things every day." In Germany, there is great pride in ingenuity and originality, in starting a project from scratch, he said. In the United States, there is pride in practicality, of making a project work. He said that Google, when it was first released, was one of several search engines, with no clear advantage. "They just kept working on it and doing it better than anyone else. In Germany, we beat on others who try to do something differently." He also raised the example of Groupon, a methodology for group buying. "There's nothing new about it," he said, "but to do it in a better, more efficient way is the culture of the Americans."

Another distinction Mr. Davidson saw was in the design of products. In Germany, he said, products are capability driven. "Think of a German car," he said. "You have so many buttons, so many features, and 90 percent of them are not needed. In the United States, products are market driven. Let's see what the market wants, and that's what we're going to make." In Germany, he said, the managers tend to be engineers, and an engineering mindset tends to dominate corporate decision making and corporate culture. The financial management, he continued, was sound, but was given more importance than it should have. "In the United States, managers are business oriented people, and marketing is the dominant theme of every company: marketing, marketing, marketing."

The Motivation of Innovators

He turned to motivation, and the importance of understanding what motivated people in small and large companies. He showed the results of a survey of thousands of employees who were asked by an American university to answer the question "What motivates you to do something?" Over 50 percent of respondents said that they were motivated when they found something challenging, when it made them curious, or when the activity seemed fun and entertaining. Another 40 percent said they would do something if it would help others, make the world a better place, bring new ideas to life, create unique events or activities, or increase their status. Of the responses, the fewest said that their primary motivation was money—both in the United States and Germany.

What pattern do good entrepreneurs follow? Mr. Davidson asked. First, they don't do it right the first time. "Some of the greatest entrepreneurs I've met in my life," he said, "billionaires today, made so many mistakes before they got it right. The culture here in Germany is not so tolerant of mistakes. Secondly, entrepreneurs dream big, and dare to fail. In the United States, we see lots of young guys, and small companies, and each one of them wants to be a billion-dollar company. Here, if you take the same guy, just as talented, coming out of a university with entrepreneurial spirit to start a company, he'll imagine making a 10 million Euro company, that's good enough for him. To break even, get a good salary, go home at five, kiss the wife, and go have beer with friends. They don't dream as big."

Using Courage on Different Paths

To illustrate the gap further, he assumed that "we all have courage—all those acting as entrepreneurs, early-stage investors, even executives of large firms. But we use it in different ways." In the United States, he said, such a person would arrange to "work first in a factory, build a prototype, take it to market, talk to friends and potential customers, and make a decision about whether this is the final product, meanwhile gaining knowledge throughout the process." The same person with courage in Germany would "first learn the subject, read books, do some research, gain a lot of wisdom, then after one or two years probably go and study the market carefully." The two entrepreneurs might finally end up at the same place, he said, but their paths would be quite different.

"What we [at Hasso Plattner Ventures] are trying to do is to combine these two cultures into one," he said. The firm works with a variety of actors: German companies, many German people with American roots, American CEOs—and they are trying to meld the international cultures to improve performance. After five years, the firm has invested in 20 companies, and several of them are profitable. It has 740 employees, a portfolio of $82 million, and 5 investors, in the EU and United States. It works in hands-on fashion with each company. "We work with the entrepreneurs, we have our own technology

park, a beautiful work place, a young and dynamic management team, and whatever we do, we do with passion."

Mr. Davidson closed by recalling when he began to invest in Germany; he talked with many local entrepreneurs, students, and professors about how to start companies. "I told them, 'Whatever you do, do it with passion.' That was actually the first word I learned in German, "— *litenshot*," he said. "And when I said "*litenshot*," they all looked at me very surprised, because you're not supposed to have fun when you're working. "*Litenshot*" is my model in life and in business, and that's what I'm doing here in Germany."

TRENDS AND CHALLENGES FOR VENTURE CAPITAL IN THE UNITED STATES

Arati Prabhakar
Partner
U.S. Venture Partners

Dr. Prabhakar said she would talk about venture capital in the United States through the lens of one sector—clean energy technologies—"which I am passionate about." This is a sector of great entrepreneurial progress and, at the same time, great risk. She reiterated Ms. Lew's observation that entrepreneurship "is all about a culture of celebrating success, but also tolerating failure; of dreaming big, and daring to fail." She said that she had been "allowed to dream big" in Silicon Valley for the last 14 years, and previously in government for 13 years, in Washington. "I dared to fail, and indeed I did fail, and they were important experiences for me. Those are the lenses through which I think about what's happening in the clean energy sector today."

The Focus on Energy Security

She gave a sketch of the overall energy system, which she said is really two energy systems: transportation, driven primarily by petroleum, and electricity, driven by many sources. There are huge challenges for this system globally, just as there are in the United States, she said, and it is often forgotten that not all of those challenges align. In the United States, for example, a major focus is energy security and energy independence, because so much petroleum is imported, especially from OPEC nations. Therefore, energy independence and overall energy strategy begins with reducing dependence on imported oil.

However, Dr. Prabhakar continued, energy independence says little about coal, of which the United States has vast stores. While this resource increases energy independence, those who wish to tackle the global warming and greenhouse gas issues see it as a major source of CO_2 and other pollutants. Natural gas, which is abundant and adds to energy independence, is a "mixed story," much cleaner than coal as a source of electricity but also a producer of carbon, so that it is best viewed as a transition step toward a carbon-free future.

One point that draws general agreement, she said, is that energy efficiency is wholly beneficial. "It continues to be staggering to see how much energy is not constructively used in the system."

Underlying all considerations for the energy system, she said, is the importance of cheap, widely available energy as a driver of economic growth. "Somehow we have to meet the energy challenge of providing supply while maintaining 'cheap and available'."

Innovation will be essential in achieving a clean-tech energy system, Dr. Prabhakar said, and "fortunately, the good news is that the tech pot is bubbling. The number of new ideas is astonishing and energizing," she said, displaying a long list of current experimental sources: artificial photosynthesis, wave power, metal-air batteries, compact modular reactors, electrofuels (CO_2 to liquid), flow batteries, algae, LED lighting, and fusion.

The Importance of Capital in Moving Toward Clean Tech

"This is the good news," she said. "The next question is, what does it take to get from these innovative ideas to real solutions?" To answer that question, she turned to the importance of capital in moving toward clean tech, and there she saw significant barriers. "We have to understand what's happening with capital at a deeper level than usual," she said. "In the R&D community, the assumption is, 'We'll do R&D, and by some miracle capital will be deployed and this new technology will be commercialized and scaled.' In fact, that isn't really happening."

Dr. Prabhakar showed a graph based on investment data from the Pew Charitable Trust on investments in clean energy technology. The investments were divided into four categories of capital: VC/private equity, public markets, asset finance,[37] and small distributed capacity.[38] The last two categories, she said, are the two most important ways for stimulate deployment of technology. "They are not about developing new technologies or starting companies," she said. "They are about markets and market pull. This whole set of investments has to equilibrate and work as a system. That means if we don't have adequate capital to deploy these technologies, all the R&D investment and VC/private equity will be no more effective than pushing on a noodle. That's why I think this is such an important context."

The total amount of financing invested in clean energy in 2010 was about $250 billion, she said, which was "a fairly healthy amount, considering

[37]Asset financing is the use of balance sheet assets (accounts receivable, short-term investments, inventory) to obtain a loan or borrow money. This differs from traditional financing that is raised through the issue of debt or equity securities.

[38]An example of investing in small distributed capacity is Germany's federal support program for photovoltaics, dispersed widely in the form of rooftop installations.

that we spend somewhat over a $1 trillion a year on energy infrastructure. The clean portion of that is now sizeable."

Dr. Prabhakar turned to a graph illustrating how that investment was distributed across nations. "For the United States," she said, "this is a sobering chart. China is outspending everybody. Germany has now taken second place, largely through the large investments in photovoltaics. The United States is third. We are not used to being third."

The Need for a Private Market in Clean Tech

Even more important was the U.S. energy mix, she said. The U.S. investments primarily take the form of VC and private equity. When these are removed, the United States is "dramatically farther behind in what's left—asset finance and small distributed capacity." She pointed to one more level of detail: whether sources of this capital are public or private. In China, it is often difficult to differentiate, "but it's clearly largely publicly driven." In the case of Germany, she asked for feedback. In the United States, the Department of Energy loan guarantee program is substantial, but it depends on public capital. "How this chart develops will be important over the next few years," she said, "in terms of our competitiveness. If the private market for clean tech does not continue to grow in the United States, these investments creating new push will shift to other places."

Turning to the topic of venture capital, Dr. Prabhakar said that clean tech had grown to 15 percent of total VC, a "notable fraction" worth $3 to $4 billion a year. "A decade ago it was virtually invisible. This is a good sign," she said, "especially since most of the rest of venture capital is going into IT, and an increasing portion is going to companies that don't have core technology in them, like digital media and 'web 2.0.' Those are building on a big layer of earlier technology but not new core tech. And clean tech has to compete against that for investments."

Recent events are sobering, she said. Firms first entered this area with a burst of enthusiasm and a sense that trillion-dollar industries were going to be transformed, with venture capital as an important partner. Then, over the past few years, a shift occurred in the way VC is approaching clean tech. This was caused by both the technology and by manufacturing issues. Many early investments in clean tech focused on photovoltaics, batteries, and other technologies with "deep materials" components. Gradually, however, the field "rediscovered" that materials "are a challenging way to make quick returns." A firm can often invest in a new material for many years "before knowing if it is anywhere near the finish line. The amount of capital it can take before an end is in sight is a daunting prospect for venture," she said. "They think, 'That's the material of the future.' But too often the material remains in the future, and there it stays."

Even if the materials problem can be solved, Dr. Prabhakar continued, a factory has to be built, "and once you build a factory, your entire business is

structured around filling it. That immense capital that has been deployed has to be used efficiently, and if you're not shipping at full volume, you're burning capital at a painful rate. A factory becomes an anchor around your neck. That's something we learned 20 years ago when semiconductors shifted to a fabless business model and let Taiwan build the foundries."

Market Restraints for Clean Tech

Dr. Prabhakar also described several significant problems on the market side. First, VC in the United States is focused on finding markets that "explode," with investors hoping for $100 or $200 million in revenue within four or six years ."Those are the rock stars of entrepreneurship," she said, "that make VC an exciting asset category." But in clean tech, she said, industries move much more slowly. For many years, the VC industry was reluctant to back companies in the automotive industry because it moves slowly and faces heavy pricing pressure. "Now we're talking about selling to utilities," she said, "which make auto companies look fast." Also, she said, VC firms prefer companies with products and services so valuable to their customers that they can charge a premium. That is the opposite of most energy companies, which deliver a kilowatt-hour or some other form of energy in a market where they have to compete on cost. "That is another killer," she said. Finally, she pointed out that VC was accustomed to industries where government policy is not a factor, or where a sound R&D base has already been developed with government funding. With clean tech, where the regulatory picture is not fully known, especially in the United States, the risks of policy changes are substantial.

The fundamental question about the role of venture capital in clean tech, she summarized, is whether VC will be a significant force in transforming the energy system. "Many passionate investors wish for that," she said, "but I suspect that it may not be the case." She cited several reasons. First, even though a lack of capital is not the problem, the competitive pressures on the VC industry cause many firms to avoid clean technologies that might require expensive factories in favor of less capital-intensive business opportunities, such as energy efficiency or IT-like products that are not manufactured. "I think that's healthy," she said, "because it will allow VC to begin generating venture returns in clean tech, and that has to happen. On the other hand, it makes it less likely that venture will play a core role in the overall transformation of the energy system."

DISCUSSION

A participant commented that Dr. Prabhakar had presented a "rather negative view of VC." She responded that a more positive view for VC would first require the creation of markets for clean tech. And to unleash enough private capital to mobilize industries and create markets will take the alignment of multiple policies. "No single policy, such as a price on carbon, is enough. We

need renewable portfolio standards and the use of government procurement to start the ball rolling."

In addition, she said, there are still barriers in demonstrating and scaling these technologies and in supporting early production. She agreed with Dr. Wessner that there are "many valleys of death, in this sense." A major one is encountered between the point when a technology is proven and the point when financing is available for the first commercial plants. "Commercial capital does not know how to go after that problem," she said. "Loan guarantees from the government are needed."

Dr. Neuhoff asked Mr. Davidson about his challenges in investing in manufacturing capacity, and whether he had enough capital. Dr. Davidson said his firm did have sufficient capital. VCs are short-term investors, he said, "which means we invest long enough to bring the company to the next level when it can raise money from external, much larger investors or hand over the company even before it's profitable. We can initiate this with relatively small amounts, especially in Germany, because public funds are readily available. It is more difficult to find the right people to deploy. Many of the best technologies we see stay within the R&D groups of Fraunhofer, Max Planck, and universities. Rarely do we find people who are ready to take risk, move out of their comfort zone, and start a new company. Our biggest constraint is the lack of entrepreneurs to start companies."

He suggested that entrepreneurism should be promoted more strongly by government policy, beginning early during education. "To become an entrepreneur and to dare to fail is fine, and should be part of the culture, which it's not at the moment," he said. "I see it in the Hasso Plattner Institute, which is near Hasso Plattner Ventures, in Potsdam. The most talented students in Germany, such as IT students, would rather start working when they're 22 or 23 years old at Deutsch Telekom or Daimler Chrysler or Microsoft rather than start their own company. In the United States, it's exactly the opposite. Here they are very old when they are very young because they don't have the right education."

Panel VII

Policies and Programs for CO_2 Reduction

Moderator:
Claudia Kemfert
Head of the Energy, Transportation, and Environment Department
German Institute for Economic Research (DIW Berlin)

Dr. Kemfert, who was scheduled to introduce Panel VII, was not able to attend the symposium because a volcanic eruption in Iceland had disrupted air travel. She was replaced by her colleague Dr. Frauke Braun, who introduced herself as a researcher in the Department of Energy, Transportation, and the Environment at the DIW.

"This is a topic that is at the core of our interest and research," she began. She summarized the EU roadmap for moving to a low-carbon society by 2050, including 2020 targets of reducing greenhouse gas emissions by 20 percent compared to 1990 levels and cutting primary energy use by 20 percent through efficiencies and the use of renewables. The targets for 2050 are far more ambitious, and very close to a low-carbon economy. The call for an 80 percent reduction in greenhouse gas emissions that, she said, could be accomplished through substantial investments in renewable energy and smart grids, and greater focus on energy efficiency, and transportation, especially electromobility. Additional gains can be made by reducing CO_2 emissions in agriculture and other sectors. "To reach these ambitious targets," she said, "requires innovation and technological change." With no changes in current policy, GHG emissions would decrease only 40 percent, not 80 percent.

More broadly, Dr. Braun summarized an EU White Paper on Sustainable mobility, which recommended the following measures to hasten progress toward 2050 goals:

- CO_2 standards and smart taxation systems.
- Improved efficiency.
- Better demand-side management pricing schemes to tackle congestion and air pollution, infrastructure.

- Intelligent city planning and improving public transport (more charging).
- Hybrid engine technologies.
- Sustainable biofuels.
- Gradual transition toward large-scale penetration of cleaner vehicles in all transport modes, including plug-in hybrids and electric vehicles (powered by batteries or fuel cells) at a later stage.

A major part of the strategy, she said, is promotion of more energy efficient buildings. New buildings constructed from 2021 onward will have to be nearly zero-energy buildings. To attain this, existing building stock will need energy-saving building components and equipment costing up to 200 billion Euros over 10 years, along with low-carbon electricity and heating.

The EU Commission had estimated the need for public and private investments of about 270 billion Euros annually for 40 years to reach this low-carbon future by 2050, she said. At the same time, decarbonizing would bring benefits. Energy efficiency can reduce the EU's average fuel costs by between 175 and 320 billion Euros per year. This would be accompanied by substantial creation of new jobs in deploying renewables, low-carbon technologies, investments, and especially energy efficiency. Already the work force of the renewable energy industry has increased by about 230,000 to 500,000 persons EU-wide in the past five years.

Germany's own Roadmap 2050, she said, was aligned with that of the EU, sharing the major goals. In addition to the 80 percent reduction in GHGs, it envisions an 80 percent share of renewable energy in electricity generation and a 50 percent reduction in primary energy consumption by 2050. A particular priority area has always been energy efficiency in buildings, where most EU countries currently lag.

Dr. Braun concluded by summarizing some of the estimated impacts of the energy efficiency strategy. The minimum required investments in efficiency by 2020 are estimated at 100 billion Euros for smart grids, 25 billion Euros for insulation, and 50 billion Euros for sustainable mobility. Public spending will be divided among R&D, an energy and climate fund, and financial support for new building. The price of electricity is estimated to rise slightly, by 1 to 5 percent, and total emissions to rise by some 25 million tons, or about 9 percent. On the positive side, 20 million Euros per year in energy savings are anticipated, along with many new.

THE "MORGENSTADT" CONCEPT

Frauke Lohr
Senior Partner, Grolman.Result GmbH[39]

Dr. Lohr introduced herself by saying that she was responsible for designing and facilitating the planning of the Morgenstadt Concept, to be executed in partnership by the federal government and the private sector. Morgenstadt can be translated as "Tomorrow-town," a concept that incorporates many of the features we might expect in the living environment of the coming decades.

The High-Tech Strategy for Germany[40], of which the Morgenstadt Concept is a part, has been developed primarily by the federal government, she began. Its goal is to help create and nurture markets, deepen and broaden the cooperation between science and industry, and foster innovation as a basis for national health and well-being. The high-tech strategy is a mission-oriented approach designed to establish Germany as a pioneer in science- and technology-based solutions in five areas: climate and energy, health and nutrition, mobility, safety, and communication. As part of the High-Tech Strategy, 11 "forward looking projects" have also been identified as fields of activity. The task for the planners of Tomorrow-town was to develop a visionary concept for illustration purposes—not only for Morgenstadt, but also for other forward-looking projects that might cumulatively create a picture of the future as well as a communication tool. The project seeks to "have something in writing" as the starting point of "a big dream" that can help society reach desirable but challenging goals.

The basic idea behind Tomorrow-town, she continued, is to prepare for challenges already known, beginning with patterns of living. While cities cover only about 1 percent of the earth's surface, for example, they generate 75 percent of global energy demand and about 80 percent of greenhouse gas emissions, primarily carbon dioxide. By the year 2050, approximately 70 percent of the world population will live in cities.

Because cities will be the first areas to confront the major challenges anticipated by scientists—climate changes, shortage of resources, population growth—the decision was made to focus on a German city which has an unusually a long history rather than using a green-field approach of building something from scratch, which is sometimes much easier.

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[39]Grolman.Result is a private consulting firm that specializes in the development and implementation of strategies within an organization.

[40]The High-Tech Strategy 2020 for Germany is a major planning document of the DIW, first produced in 2006 and updated in 2010. The aim of the High-Tech Strategy (HTS) is "to create lead markets, intensify cooperation between science and industry, and continue to improve the general conditions for innovation." <*http://www.bmbf.de/en/6618.php*>.

Achieving a Carbon-dioxide-neutral City

There are many ways to achieve the goal of a carbon-dioxide neutral city, she said. The visionary concept of Tomorrow-town is a normative scenario chosen by a diverse group from the federal government. Some 20 experts, including electrical engineers, city planners, transportation engineers, and sociologists, worked for three months with political decision makers and experts from industry and presented their result to the public in November 2010. It was published in the leading German newspaper, *Frankfurt Allgemeine Zeitung*, where it was called "a green dream."

The Tomorrow-town vision addressed major features of city life, including energy, transportation, city planning, spaces, and decision making. She began to look at these features in the year 2030. By then, new houses will be zero-energy buildings, required to produce at least as much energy as they consume. Many older buildings will have been rehabilitated through new, thin thermal insulations that do not conflict with preservation. Every fifth house has reached passive house standards. Hybrid solar collectors on the roof produce not only solar energy but also heat. Renters can buy share certificates with their rental agreements. The heating system is carbon-neutral. In 2010, heating has caused almost half of carbon dioxide emissions, and these have been reduced to near zero. This aspect of Tomorrow-town won an award from the German Solar League, a body that tracks carbon dioxide emissions per inhabitant.

The energy scenario for Tomorrow-town combines heating and power generation. Waste heat from electricity production is distributed through a network of tubes and, in some areas, heat pumps and solar collectors are used. Biomass is the main energy source for public heating plants, and this is also distributed through the gas tube network. These systems are complemented by decentralized renewable sources, such as solar panels on houses and hydraulic power plants. Such renewable electricity is imported via highly efficient grids, mainly from wind and solar energy.

Tomorrow-town's energy supply is both safe and cheap, she continued. Utility companies are the service providers, acting as agents to balance supply and demand and as managers integrating centralized and decentralized networks. The population must learn that there are fluctuations in supply and rates, depending on when production abundances or shortages are imminent. New technologies of energy storage have reduced these fluctuations, with electric cars playing a major role in load compensation. Excess electricity is stored electro-chemically in hydrogen and used in fuel cells. Smart grids include intelligent control of building heating and cooling. Sensors ensure that electricity for light and temperature control is used only when necessary and that washing machines and dishwashers are run when energy is cheapest. Most inhabitants have become "pro-sumers," both producing and consuming energy. Technical progress has made the necessary investments affordable.

Transportation in Tomorrow-town will feature smart traffic management systems that enable smooth flows despite increased volume; part of the increase will be caused by the increase in one- and two- person households. Vehicles are capable of communicating with each other and with the infrastructure. Electric cars will predominate, thanks to incentives like free tolls and parking; this lowers pollution and noise levels. Public transportation is optimized and extended, and tariffs are subsidized. The system is convenient, clean, safe, and user-friendly, providing real-time information on connections, schedules, and events.

Transportation is further enhanced through a variety of mobility concepts. For example, an e-car or e-bike can be rented by mobile phone. Rentals as well as public transportation at flexible rates is paid for with mobility cards. These conveniences induce more people to do without their own car, or second car. An advanced system of foot and bike paths complements the mobility infrastructure. New cargo concepts allow for a more efficient distribution of goods. These goods include cargo trams, e-vehicles, cargo tubes, barges, and special cargo transport centers on the urban fringes. "In Tomorrow-town," she said, "the traffic flows smoothly despite increased volumes."

As cities have evolved over time, planning has been complicated by the mixing of residential and commercial quarters, especially in cities of eastern Germany. This mixing of quarters, each with a strong identity, will continue, complemented by a mixture of social strata, cultures, and generations. Examples are seen in Munich, where one sees collaboratively used infrastructure, such as shared greenhouses on the roof, solar panels, and car sharing. Other forms of cooperation will be needed to overcome social conflicts.

Urban spaces have been redesigned. With more travel by foot or bicycle, less space is needed for cars. Residential areas that cannot be made energy-efficient have been dismantled. Green corridors, community gardens, and vegetation along bike paths and sidewalks provide better air quality. Heat is generated from sewage water, and biogas from sewage treatment produces electricity; gray water irrigates community gardens. The city is a place of short distances and higher quality of living.

Creating Tomorrow-town will depend on cooperative and interdisciplinary decision making by engineers, consultants, service providers, and technology suppliers. Communities must have autonomy in addressing local planning and energy issues. Development will make use of intensive data analysis and management to analyze and optimize the flows of people and vehicles, and to optimize energy and water use. For traffic systems, cost-transparency must be explicit and clear to the public. People are encouraged—beginning in school years—to understand the need for new systems and to participate fully. Energy and resource efficiency become part of school curricula, as do climate and energy management and many other new fields of study.

Tomorrow-town, she summarized, is a city of participatory decision-making and consequent action, and ongoing dialogue between all parties. "We must integrate everything in order to make the big dream happen," she said.

Dr. Lohr summarized the characteristics of Tomorrow-town as follows:

- The heat supply is almost carbon dioxide neutral.
- Energy cost-savings are significant.
- Traffic flow is optimized with fewer perturbations.
- The quality of life is high.
- Success depends on participatory decision-making and cooperative action.

"Tomorrow-town has a chance to become an economically prospering and livable city," she concluded. "I've just presented a challenging big green dream." The dream, she acknowledged, is ambitious, but has the support of the Industry-Science Research Alliance[41] and many others. She also acknowledged a truth she had learned during the development of the concept: The real challenge of reaching Tomorrow-town lies not so much in developing technical details as in integrating existing solutions and winning the support and participation of the public. "Our real task," she concluded, is to make the people aware that the cities of the past will no longer be possible in the 21st century, and that "there is no other way to move forward into the cities of the future."

U.S. CARBON REDUCTION POLICIES

Charles Ebinger
Director, Energy Security Initiative
The Brookings Institution

Dr. Ebinger began by "setting the stage" on a paramount feature of any discussion of energy, which is very rapid global change. According to the International Energy Agency, the world will need $30 trillion of investment in energy production, transmission, and distribution by 2030. "That is totally prodigious," he said. Also, as planners discuss shifting away from fossil fuels toward renewable fuels and energy efficiency, they need to keep sight of the 1.5 billion people in the world today who have no electricity—not even enough for a light bulb or a fan. "Clearly," he said, "if we're going to have an equitable society at the global level, we have to find a way to bring those people into the modern era at the same time we transform our existing energy infrastructure."

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[41]The Industry-Science Research Alliance was initiated by the Federal Research Ministry in 2006. It is a forum in which leading representatives from science and industry propose strategies for strengthening Germany as a high-tech location. <*http://www.hightech-strategie.de/en/81.php*>.

Finally, he said, as countries ponder the use of less coal, they need to remember that coal accounts for 80 percent of China's energy use, and 50 percent of the energy of the United States' energy use. "Coal," he said, "is not going away any time soon. If you think it might or wish it might, keep in mind that countries where coal is a major energy source, such as India, also depend on it as one of the biggest employers of people. So to take on the coal industry is to venture into very dangerous political ground."

Dr. Ebinger gave the Obama administration credit for "moving much farther on energy efficiency and renewable energy than any previous administration—at least since the Carter administration's early efforts." From a climate perspective, he said, President Obama in Copenhagen committed in late 2009 to cutting U.S. CO_2 emissions by 17 percent by 2020—below 2005 levels—and by 80 percent by 2050. Although many people, particularly in Europe, criticized the administration for not setting higher goals sooner, "the President was, I think, very lucky to get even that degree of commitment." That commitment, however, was tied to the passage of climate change legislation in the U.S. Congress, and both bills died in committee.

Since the country's failure to attack CO_2 emissions through legislation, the president has turned to a different narrative, focusing on the economy and the way renewable energy and energy efficiency create new jobs. Such environmental policies have little support from U.S. voters, however, if they raise energy prices. "Voters are more concerned in the current economic crisis with job creation and economic recovery," he said. "The Obama administration as a result has largely abandoned its climate change efforts and has instead tried to attack the problem from an economic view. Environmental and clean energy policies are now recast as policies for economic growth and for U.S. competitiveness, while energy security has become a larger priority. He sought to lower expectations that the United States would achieve 'energy independence.' This is something we can't do, and I'm not even sure it would be good if we tried." Given the amount of energy the U.S. imports, he said, it probably cannot be replaced before the end of the century.

Turning to the Obama administration's policies, Dr. Ebinger said that in 2011 the administration had announced a number of clean energy initiatives. The president reduced his support for renewable portfolio standards, by which state legislatures mandate a proportion of their energy portfolio to be produced by renewable sources by a certain date. Instead, the president supported a national clean energy standard that focuses almost exclusively on renewables, particularly wind, solar, and biomass. The National Clean Energy Standard takes a much broader view of energy and includes not only renewables, but also nuclear energy, hydropower, natural gas, and clean coal.

The president also called for cleaner transportation, proposing new additional standards that would go into effect by 2014 and 2015. He also called for one million electric vehicles by 2015, a target Mr. Ebinger regarded with caution. "In the United States, even the most optimistic projections I've seen predict 10 million electric vehicles by 2030, and I think most people would

consider that bold." There are about 260 million vehicles on the road today, so while a goal of 1 million or even more is vital, he said, "it means that in the transportation sector we are going to remain dependent on imported oil for a significant time."

Dr. Ebinger mentioned several bills before Congress that promote the use of natural gas in heavy trucks, but noted that this would require a new refueling infrastructure along interstate highways that would cost billions of dollars. Infrastructure in general is a major challenge, he said, one that many in Congress seem not to understand. While the country has abundant wind and solar resources, most of the wind blows on the Great Plains, and the most of the sunshine falls on the desert Southwest. Both resources are far from major load centers; optimizing would require replacement of the national grid system with a high-voltage, direct transmission/direct current (DC) grid. In a DC grid, he said, power can travel much larger distances with much lower line losses. But the lowest cost estimate from the Federal Energy Regulatory Commission for installing a DC grid is $350 billion, and estimates from McKenzie and Company, he said, are $500 or $600 billion. In addition to financing, such a project would require reconciling the regulatory rules of all 50 states, including the diverse interests of investor-owned utilities, municipal utilities, some federal utilities, and regional transmission organizations. In addition, about half the states have regulated markets and the rest have deregulated markets, and this divide will impede institutional change as well.

Continuing with Obama administration policies, Dr. Ebinger reviewed the major investments in energy under the stimulus program of 2009. Energy efficiency was the largest single component; the others were carbon capture and storage, efficient vehicles, renewables, energy innovation, and environmental cleanup. In 2012 the administration asked for significant additional funds for all of these energy initiatives.

One of the most controversial government measures was to allow the Environmental Protection Administration authority to regulate greenhouse gas emissions under the Clean Air Act. "This was anathema to many Republicans in Congress, and it will probably end up going to the Supreme Court," he said. "It will undoubtedly be challenged when the EPA actually embarks on this. The EPA has been accused of overstepping its regulatory authority, but it's generally seen as a possible way of reducing emissions without having to pass climate change legislation."

Regarding the future of the U.S. carbon reduction efforts Dr. Ebinger said that "sweeping changes are unlikely," and will be restricted to an "economic" agenda by strong political opposition. Energy security will continue to be the focus, especially domestic oil and gas production, and the increased use of natural gas for electricity generation. He said that the discovery of shale gas is "far more transformative than anyone realizes," bringing the "very real prospect of expanding she share of natural gas in electricity generation from the 20 percent today to 30 or 35 percent, and remaining there for 50 to 100 years." Shale gas, he said, can be developed for $4.50 to $5.50 per million BTU, with

the upper range of those figures equivalent to $40 or less per barrel of oil. "And shale gas I think will have a rippling effect throughout the world, as the United States no longer needs to import liquefied natural gas."

Nuclear power, he said, is not popular in the United States, "but the president continues to talk about it as part of the energy mix. While only one new plant is under construction, the administration continues to say that nuclear energy is important to meeting its goal."

What is likely to happen, Dr. Ebinger said, is change at the state and local levels "where we're seeing a lot of activity." Some 30 states already have renewable portfolio standards, while the federal government does not, and many more are studying them. "On balance," he concluded, "we have an administration deeply committed to reducing climate change. It may not sound that way at formal international meetings, such as those in Cancun and Copenhagen, but behind the scenes, through the EPA and through bold initiatives that we'll hear more about today, I think you should be optimistic. You can take solace that this administration is deeply committed to action on climate change and deeply concerned about the threat it poses to the planet. If this administration has a second term, I think you'll see even more bold initiatives in the future."

CLIMATE CHANGE AND INNOVATION: MITIGATION AND ADAPTATION MEASURES

Reinhard F. Hüttl
Scientific Executive Director, Helmholtz Centre Potsdam/GFZ
and
President, acatech, the German Academy of Science and Engineering

Despite Germany's long tradition in science and the world of academia, Dr. Hüttl began, it has only recently established two national academies—the National Academy of Science and Engineering and the National Academy of Sciences (acatech). Both are funded by the 16 federated states, the federal government, and industry. The mission of the academies, in addition to providing a platform for exchanging knowledge between science and society and promoting the careers of young scientists and engineers, is to provide fact-based advice to the general public and to politicians involved in policymaking. Dr. Hüttl serves as acatech president, and is also a member of the academy's ethics commission for a secure energy supply; that commission was scheduled to give its recommendations to the chancellor during the week following the symposium.

He began his discussion of climate change with a paradox: Even as nations face many challenges in deciding which technologies, innovations, and policies might be most useful in addressing climate change, climate change itself is an important driver of new technologies and innovation. Other drivers include global knowledge, customers and users, and the challenge of promoting a public

understanding of science. He described a "long-term interrelation" between innovation and sustainability, with innovation enabling sustainability through new products and processes, and sustainability in turn driving innovation through global challenges.

Dr. Hüttl also serves as director of Germany's national laboratory on geosciences, in Potsdam, where the research framework is titled "System Earth." He said that System Earth is understood as a complex entity consisting of the geosphere, hydrosphere, cryosphere, biosphere, and atmosphere. Climate is a subsystem related to all five "spheres." The significant change in climate in recent times is the increased concentration of so-called greenhouse gases (GHGs), especially CO_2, in the atmosphere. To understand this increase and what it means for the future, he said, the laboratory looks to the past and the natural dynamics recorded in various geological records. "Only when we understand natural dynamics," he said, "can we have a better understand of how the activities of humans have an impact on climate."

Since about 600 million years ago, when "life exploded on our planet earth," first under marine conditions and then on land, there have been four great ice ages, alternating with four warm periods when there was no ice. During the earliest periods, we have few records to help understand the causes of fluctuations. More recently, we can see correlations with such earth parameters as its elliptical orbit and tilted axis. The best-known era began about 130,000 years ago, when Earth entered a long period of glaciation and then emerged into the current warming phase about 11,000 years ago.

"To give an idea of the extent of this change," Dr. Hüttl said, "where we are sitting in Berlin was covered about 15,000 years ago with ice about 1,000 meters thick. Then, all of a sudden, it became warmer, the ice melted, and we moved to pleasant conditions. If you go back 50 million years and dig down into the crust where we are sitting, you would find brown coal. This means we had subtropical climate conditions and it was very warm, humid, and good for vegetation."

We have now been living for about 10,000 years under conditions of warming, although still with fluctuations. During the Roman Empire, some 2,000 years ago, the climate was warm enough to allow Hannibal to lead elephants across the Alps. This period was followed more recently by a "Little Ice Age" which lasted about 400 years, bottoming out around 1600 C.E. After that, human activities began to influence climate dynamics, chiefly by releasing fossil carbons.

"What we clearly can see," he said, "is that GHGs related to human activity, especially from fossil fuels, is relevant to climate dynamics. But there are also natural factors that we cannot omit. So the idea that man really can control climate dynamics is not scientifically backed. This is an important message. When I was responsible for coordinating climate research standards for our government, we said yes, we have to reduce CO_2 in the atmosphere, and certainly much of the CO_2 would not be there if humans had not been active. But to conclude form this that we can control climate, we said no."

Dr. Hüttl said there were two responses to climate change: mitigation and adaptation. Mitigation has been studied by many people at different scales. Proposals have included the Kyoto Protocol, the Integrated Energy and Climate Program, use of renewable energy sources, and carbon capture and sequestration. Germany's national target for 2020 is to reduce carbon emissions by 40 percent relative to 1990.

A central strategy of mitigation, he said, is to capture CO_2 from waste emissions. Germany is the largest producer of lignite, or soft coal, which accounts for about 30 percent of electricity production. "This is a very bad source in terms of energy production and high level of CO_2 emission," he said. Therefore carbon capture is important for Germany, and geologists have recommended storing it below cap rock in a saline aquifer near Potsdam—near where lignite is mined. "But the people don't like it," he said. "We have no acceptance for this technology here in Germany. Some people think that CO_2 is dangerous, like nuclear waste. Of course this is not true, but this is the perception."

Adaptation, he said, included the need to adapt to specific regional effects of global climate change. "We see this as an innovation pathway, to develop resilience to potential damages." Germany released a National Adaptation Strategy in 2008 and was drafting a National Adaptation Plan. It describes implementation for different industrial sectors, including energy, water, transport, and communication. Required, he said, were more research, advocacy, and capacity building.

To illustrate the consequences of climate change locally, Dr. Hüttl said that even in a small country such as Germany, modest changes in precipitation and temperature over the past century had brought notable changes, both positive and negative. At higher elevations, such as the Black Forest, higher temperatures and more precipitation had brought longer growth periods and healthier forests with more species. In the lowlands of Brandenburg, around Berlin, longer periods of higher temperatures had brought a transition from mostly pine forests to mixed pine-deciduous forests and more species competition. This more stable ecosystem is important for not only wood production, he said, but also for better water resources, biodiversity, clean air, and recreation. On the other hand, more wood production is associated with mobilization of humus and release of CO_2 from the soil. "This is important in terms of CO_2 balances and budgets when we compute them," he said.

Overall, Dr. Hüttl concluded, "when you look at System Earth you have to say, yes, man has become a geofactor. Man is influencing our planet. So both concepts, mitigation and adaptation to climate change, are important. And more effort is necessary to understand everything that is happening. Of course changing the energy supply is important, but it will not solve the whole problem."

DISCUSSION

A questioner asked about financing renewable energy systems, such as rooftop photovoltaics. Dr. Lohr said that most financing goes into the development of technology, with only a small amount going into actual electricity supply infrastructure. "There is a clear imbalance between investments in technology," she said, "versus what you get out in terms of renewable energy." She said that while people are generating electricity for their houses, they don't use the electricity they generate, which is transferred into the public net from the house owners, who then buy it back. "This is not a very convincing situation in the long run," she said.

Dr. Wessner asked about the process of phasing out nuclear power in Germany. Dr. Hüttl said that Germany had previously decided to exit the nuclear sector, and the Fukushima disaster in Japan provided the stimulus to do so "faster than expected." He said that the decision was settled, and the change would occur over about a decade. "You cannot set a clear time limit," he said. "It's more of a corridor. You can only let go of the existing supply system when you have a substitute ready. This is the challenge, to organize the substitute."

The substitutes on the menu, he said, include the renewables—wind, sun, water, perhaps geothermal power—and other sources. Germany will use more natural gas, and examine clean shale gas and clean coal. It will address not just the question of carbon capture and sequestration, but also whether CO_2 can be used as a raw material for methanol. "For instance, when you have an oversupply of wind power, we may use it for electrolysis of water to produce hydrogen, combine it with captured CO_2 to make methane or methanol, and maybe store it."

There are more concepts, he said, including "research maybe far down the road on artificial photosynthesis, and production of algae. There will be some storage, maybe some in the sea, in gas hydrates to replace methane for CO_2. There will be enhanced oil recovery using CO_2 to increase pressure in the ground and force more oil from reservoirs that are depleted only to 40 or 50 percent today."

"Getting out of nuclear," he said, "doesn't mean just shutting down the power plants. It means to answer the question of what to do with the nuclear waste. Are there processes to reduce half-lives significantly? We will probably need reservoirs to store nuclear waste, but then we want to get it back once we have technologies to treat. Once you really secure this end of the technology, and you have inherently secure nuclear power plants, you have a secure technology. This is from my point of view the focus of our challenge today. It's not as simple as to say wind will solve the problem."

A participant commented on Minister Hoyer's description of values shared across the Atlantic, saying that there were actually quite different views of nuclear energy. For the United States, it remains a key part of the core portfolio; in Germany it is "way over on the other side." He moved to another question, asking whether Germany might not get a much bigger "bang for the

buck" by "paying our poor American friends to lower their carbon footprint to our German level" rather than trying to lower the level in Germany to zero.

The moderator responded that when Germany has "such an ambitious goal" as to lower its emissions to zero, it can help foster innovation through new technological solutions; these can then be exported to other parts of the world. She agreed that the financial aspect was "definitely not solved. At the end, price and demand will be the key in whether it's accepted by the population. Only if you can pay for it will people be willing to do it."

Panel VIII

Building Electric Vehicle Industries

Moderator:
Andreas Möller
Head of the Division of Policy and Social Consulting
acatech, the German Academy of Science and Engineering

Dr. Möller welcomed the participants to the panel on electromobility and the electric vehicle industry. Electromobility, he said, is "an important cornerstone of sustainable mobility, not only in the United States and Germany, but world-wide." A week earlier, the federal government of Germany had release its official two-year electromobility budget of one billion Euros, mainly for research, battery development, and lightweight construction technologies.

"The government," he said, "wants Germany to become not only an elite market, but an elite provider in electromobility worldwide. "This is an ambitious goal in a highly competitive international field with new, powerful players. An interesting point is that the government decided not to stimulate the market with buyers' incentives, like France, even there is a gap in total cost of ownership" (TCO). The German aim was to have one million cars, including both plug-in hybrids and pure electric cars, on the roads by 2020. He said that this goal would be difficult to reach without subsidies.

In the United States, Dr. Möller said, electromobility is also an important topic, with the Obama administration planning to invest more than $100 billion in new energy technologies, about $2 billion of that in electromobility—and amount similar to the budget of the Chinese government.

He introduced the two speakers, Edwin Owens and Dirk Arnold, who would address the topic for the United States and Germany.

U.S. BATTERY INITIATIVE FOR ELECTRIC DRIVE VEHICLES

Ed Owens
Supervisory General Engineer for Vehicle Technologies
U.S. Department of Energy

Mr. Owens said he would discuss the battery initiative at the U.S. Department of Energy (DoE) for electric drive vehicles, and refer as well to other programs within DoE and other agencies that encourage development of complementary technologies, such as motors and power electronics.

The DoE had been investing in battery technology for more than 30 years, he said, with improved technology and rising funding for 20 years. The budget for 2010 was $76 million; the request for 2011 was $96 million, and the request for 2012 was $140 million. The goal for 2014 was to reduce the production cost of a plug-in electric vehicle (PHEV) battery to $300/kilowatt-hour (kWh), 70 percent below current cost.

Mr. Owens suggested that the DoE's two decades of investment may be responsible for the current hybrid vehicle industry. Until this year, he said, all the hybrids on the roads of the United States contained IP developed and owned by the DoE. "We've continued to invest in the newer lithium-ion technology," he said, "and we see that technology as well reaching the marketplace. So between the nickel metal hydride batteries that came out of DoE funding and the lithium-ion technology, we see spillovers from our R&D programs directly into the marketplace."

The DoE battery technology program extends from basic research on fundamental electrochemistry through battery cell development, battery pack development, and, more recently, full-system development and support for commercialization. "This range of program and sustained support are reasons it's been so effective over the years," he said.

The research programs are driven by specific performance goals for batteries. Depending on whether the goal is a conventional hybrid; plug-in electric vehicle (PEV) with some form of range extension, like the Chevy Volt; or an all-electric vehicle, the requirements for the batteries—and therefore the technology—are different. "I don't mean you have to meet all these goals to commercialize the batteries," he said, "because some of them in vehicles today don't meet the goals. But having a set of goals provides a way to measure achievement and focus development—not only within the research community, but also for the potential battery manufacturers. Then they understand where they need to go."

Battery price is a critical issue for successful electric drive vehicles, he said, and it is too high. A few years ago batteries for hybrids cost $1,000 to $1,200 a kWh; today the price is about $600 to $700 per kWh. The DoE's short-term goal is to reach $300 by 2014, and ultimately $150. "Just large-scale production in large plants at higher volumes will not bring the cost to these levels," he said. "What's needed is improved technology with less but higher-

performing materials. We need higher-performing basic chemistry that allows the battery size to shrink and the costs to go down."

The American Reinvestment and Recovery Act (ARRA), Mr. Owens said, brought a unique opportunity to create a battery manufacturing industry in the United States. The DoE invested $2 billion in helping create and support it, and has invested another $750 million in transportation, electrification, and other measures to encourage an infrastructure for all-electric and plug-in hybrid electric vehicles. The investments have been made across the battery supply chain—from the basic materials through cell manufacturers—to encourage an industry that before ARRA did not exist in the United States. Prior to the ARRA investments, the United States had about 3 percent of the lithium-ion battery manufacturing capacity in the world. These investments and corresponding investments by the manufacturers themselves are likely to bring enough capacity to meet all U.S. demand through at least 2015, he said. An executive of a battery company had told him that new battery plants would have been built without U.S. investment, but they probably would have been built in Korea. "By using this unique and hopefully once-in-a-lifetime investment, we have seen the creation of what we believe is going to be a stable U.S. manufacturing capability."

Mr. Owens turned to battery cost and production anticipated to 2014. Both the ARRA and the Advanced Technology Vehicle Manufacturing Loan Program have been used to support development of battery production capacity in the United States. Some plants are already in production, and more are scheduled to come on line. Estimated capacity by 2015 is about 10 million kWh of automotive-scale lithium-ion batteries. "That compares well with the production capacities that have been announced for manufacturers selling to the U.S. automotive industry," he said. "These are cumulative numbers of announced capacity before GM announced that they were increasing the capacity of the Volt production facilities. Even at that time it looked like we had enough production capacity to reach 1.2 million vehicles on U.S. roads by 2015."

He emphasized that "this 1.2 million vehicles is a milestone, not an end objective;" the number represents only 0.4 percent of the U.S. vehicle fleet. "So even at this rate we're just getting our toe in the water. But it's interesting to note that production capacity and demand for these vehicles pretty well matches."

The ARRA has also allowed DoE to invest in other areas of electric drive technology—not only in motors and power electronics, but also in industrial vehicles, classes 3 through 7. These small trucks typically operate in urban areas, and are "an interesting target for early adoption of leasing PEV and electric drive." An advantage, he said, is that it is easier to sell trucks on the basis of life-cycle cost than initial purchase price.

The ARRA has also helped develop infrastructure to support plug-in and electric vehicles. The country is in the process of its largest deployment of electric-drive vehicles and charging infrastructure, deploying 13,000 electric-

drive vehicles and 22,000 charge points associated with those vehicles. One objective is to understand how individual consumers use their electric vehicles and how they charge them in order to encourage more adoption.

Part of the DoE effort is to develop codes and standards needed to smooth the introduction of new vehicles and harmonize them with partners in Europe and Asia. A goal is the ability to develop vehicles in one place that can be easily transferred or sold in another.

In summary, Mr. Owens said that DoE had been supporting battery development for several decades, and as these batteries have improved, DoE and other agencies had increased investments to support commercialization, including an increased focus on the charging infrastructure and other efforts to remove barriers. He attributed part of DoE's success to its commitment to a long-term research program that recognizes improvement and continues to support companies.

GERMAN DEVELOPMENTS IN ELECTRIC VEHICLES

Dirk Arnold
Deputy Head of Division
Environmental Innovation and Electric Mobility
Federal Ministry of Economics and Technology (BMWi)

Mr. Arnold said that the symposium was well-timed at a peak of activity for electromobility. The previous week, a report from the National Platform of Electric Mobility was presented to Chancellor Merkel, followed two days later by a government response to the report.

Electromobiity, he said, was closely related to the Integrated Energy Climate Program, initiated in 2008 by four collaborating ministries. In 2009 the government issued a stimulus package for R&D in electric vehicles, and would evaluate the results. In August 2009 a National Development Plan for Electromobility was released, with goals for 2015 and 2020. Also, the federal government had created a Joint Unit for Electromobility, and in May 2010 established a National Platform of Electromobility. His division was able to join about 150 people from industry and research to evaluate the platform's goals in developing electromobility in Germany.

Mr. Arnold summarized the activities assigned to participating ministries. The Ministry of Economics and Technology was providing grid integration and performing research in energy, IT, and transport systems, including drive components and power train. The Ministry of Transport was using its funding to stimulate eight model regions across Germany and create a battery test center. The Ministry of Environment was carrying out fleet tests, recycling lithium-ion traction batteries, and launching a commercial program for hybrid buses. Finally, the Ministry of Research focused on development of production technologies, factory systems for lithium-ion cells, and battery

systems. It also maintained a network of excellence in systematic research and developed research centers in electrochemistry.

The government platform for electromobiity had several key objectives:

- Contribute to climate protection, grid stability, and extended use of renewable energy.
- Better understand grid stability, especially in the wake of the events of Fukushima, and prepare to scale down nuclear energy.
- Support market leadership of German automotive and supply industries.
- Maintain competitiveness through innovation along the new value chain.
- Aim to be a lead supplier for EM for the automotive industry.
- Facilitate new urban mobility and road transport concepts.
- Raise public awareness and encourage EM acceptance.

A central milestone for the effort is to have one million EVs and PHEVs on Germany's roads by 2020. In order to reach that milestone, the government had established an action plan with the following contents:

- Deploy additional R&D subsidies of 1 billion Euros from the present until 2013. This would represent a doubling of the previous support, from 2009 to 2011, of 500 million Euros.
- Award tax exemptions for EVs.
- Provide a framework for EM in the form of university training and road traffic laws.
- Designate a small number of regions as showcases for EV use.
- Employ tax money in the form of R&D rather than consumer incentives.
- Employ competition as the best incentive for innovation.

Among the key challenges for R&D, he said, was energy storage. Essential goals here include lowering battery costs, enhancing energy density, extending battery life cycle, and improving safety. For vehicle technology, goals include development and improvement of electric components and electrification of ancillary units. A final goal is grid integration, including construction of charging facilities and introduction of IT technologies, time-sensitive charging, and feeding charge back to the grid.

The National Platform included several framework conditions, beginning with education and skills, battery recycling, standardization of plugs and other components, and a regulatory framework by which to identify appropriate locations for facilities. It also aimed to strengthen markets by

developing business cases, accelerating market penetration; supporting market preparation, and modeling EM showcases in various regions of the country.

Mr. Arnold emphasized that while the platform represented important perspective, "we can't do anything without industry. We need them to focus the whole effort."

He concluded on a note of strength—manufacturing the automobiles themselves. "Part of our job is development of production technologies," he said. "That's something where Germany was always very strong—creating the machines, creating the cars."

DISCUSSION

A questioner asked whether it would not be faster to import batteries rather than develop them at home so as to move electric vehicles to market more quickly.

Mr. Owens said that battery R&D programs had been "critical in getting us to where we are today, but they're not sufficient. You can develop the best technology in the world, and if you can't make it into real batteries, and those batteries into packs that service vehicles, you'll never get the vehicles on the road. That includes the safety, the standards, and the charging infrastructure. Our perspective is you have to support the battery and vehicle development from the fundamentals of the science all the way through to production."

Another participant asked how long the technology might be subsidized.

Mr. Owens said that the U.S. energy program supported five areas: active research programs in electric drive, biofuels, improved energy efficiency, fuel cells and hydrogen, and natural gas. The DoE program focused on a variety of areas that provide tools for industry. "I think that electric vehicles are getting a lot of emphasis today because they're successful. I don't see the DoE's electric program as picking a particular technology. Rather, this is one of the ones we're working on, and the market seems to prefer it, so we're going to try to help it along." He said the Congress was the only body that could determine how long the government would subsidize EV research.

Mr. Arnold said that the German government would provide subsidies for as short a period as possible. He added that the situation is complicated because of climate goals, not only for Europe but globally. "If we think that only the consumer should pay more money for expensive cars that can reach those goals, we need to help with batteries that are efficient enough, of course using an open technology."

Dr. Prabhakar said that the premium to buy an electric vehicle is about $10,000, but that the total cost of ownership (TCO) is probably lower. "What is the payoff period at the current premium?" she asked. Mr. Owens said that as gas prices rise, the payoff period shortens. But by modeling consumer use of hybrids and PHEV, even before a recent rise in fuel prices, "it appeared that in total life cycle costs, hybrids were already economically viable in the United

States. The difficulty is that consumers tend to focus on first cost." One reason for DoE's interest in class 3-8 industrial vehicles is that they are easier to sell on a life cycle basis. Those sales would increase production of batteries, bring down costs, and increase manufacturing expertise. "So anything we can do to stimulate demand for Li-ion battery technology will make the cost situation better."

Mr. Arnold said the TCO problem can be reduced by three other factors. First, battery cost will drop as batteries become more effective. Second, faster recharging will help consumer acceptance. Third, grid integration of the battery can bring reimbursement for unused electricity.

A questioner asked about disposal at the end of battery life. Mr. Owens said the DoE believes that batteries will be easily recycled, and there is also much interest in reuse. Current knowledge is limited, he said, but lifetimes are estimated at well over 10 years, "and probably longer."

Mr. Arnold agreed, and said that in Germany, the Ministry of Environmental Protection was developing recycling possibilities and on second uses of batteries before recycling. One important focus is the use of older batteries to help stabilize the grid by storing and releasing energy as needed.

Panel IX

Medical/Biomedical Innovation for the 21st Century

Moderator:
Charles W. Wessner
Director, Technology, Innovation, and Entrepreneurship
The National Academies

Dr. Wessner opened the next panel by welcoming the two speakers, Dr. Lee and Dr. Giesekus, and noting the value of hearing from two such accomplished and yet different institutions as the U.S. National Institutes of Health of Dr. Lee and the Fraunhofer Heinrich Hertz Institute of Dr. Giesekus. The National Cancer Institute was long renowned for its basic research in biomedicine, while the structure and success of the Fraunhofer program had been for some years a topic of growing interest to the U.S. policy community, he said, as a potential model for building partnerships between the public and private sectors.

ADVANCING INNOVATION AND CONVERGENCE IN CANCER RESEARCH

Jerry S. H. Lee
Deputy Director
Center for Strategic Scientific Initiatives
U.S. National Cancer Institute

Dr. Lee said that because he saw few health researchers at the symposium, he would begin with a brief overview of cancer research. Cancer, he said, is a collection of many diseases that share the similar behavior of uncontrolled cell growth. When cancer is localized in a tumor, survivability is relatively high if detected early. However, if it spreads beyond the point of origin, survivability drops. If it spreads, or metastasizes, through the lymph glands or bloodstream, the outlook drops precipitously. Some 90 percent of cancer deaths are caused by this disseminated disease or metastasis.

He then said he would try to explain why he had been invited to meeting whose primary focus was innovation. For one thing, he said, the need

for innovation in cancer research was urgent. Unlike other major disease killers, cancer continues to take nearly the same toll it did in 1950. While the death rate per 100,000 Americans from heart disease dropped from 586 in 1950 to 203 in 2008; from cerebrovascular disease from 180 to 44; and from pneumonia/influenza from 48 to 18, the death rate from cancers held steady at about half a million. Americans now spend $124 billion for cancer healthcare costs.

And cancer is not just a burden for the United States, he said. A study by the WHO indicates that by 2020 cancer would claim about 10 million lives per year, making it or one of top 10 killers. This percentage has increased since 2002, "so we truly need to think differently, which is what we are charged to do in my organization."

A second reason Dr. Lee had been invited, he said, was that his own center was specifically charged to find innovative approaches to the cancer battle. In addition, he said, it was "possibly the most exciting time to be doing biomedical research." In 2001, the full sequencing of the human genome was completed, and last year investigators in the United States, in collaboration with partners elsewhere, launched the 1000 Genomes Project to examine gene-by-gene population differences. These and other programs have generated unprecedented amounts of information that is being put into public domain.

Jump-starting the Cancer Research Process

Is this increase of knowledge benefiting the patient, he asked? Maybe, but not fast enough. "So we asked ourselves about 10 years ago whether we could jump-start this process and make it more efficient, to go from 'turning the crank' to something different. We reached out to the research community, and used the responses to identify four key needs" that might enable researchers to understand cancer. The first was better standards and protocols, so researchers can speak the same language. The second was real-time public release of data to ensure prompt availability. Third was to structure research teams with multiple disciplines. And fourth was to create an environment conducive to innovation. "If we could do all this," he said, "we would have the potential to transform cancer, drug discovery, and diagnostics."

These were daunting needs, Dr. Lee said, but his advisory group reported them directly to the president. The Center for Strategic Scientific Initiatives used exactly those needs to structure its mission—to build "…trans-disciplinary approaches, infrastructures, and standards to accelerate the creation and broad deployment of data, knowledge, and tools to empower the entire cancer research continuum…for patient benefit…"

His group then set out to answer their "big question": why does cancer research not move faster? A central problem, he said, was that while everyone understood that cancer is caused by an alteration of genes, many had different perspectives on which changes were truly important. "So we said, let's do a systemic identification of all the cancer genomic changes, repeat if for all

cancers, and make it publically available." He launched a new Cancer Genome Atlas for three cancers: brain, lung and ovarian. The center collected data on every patient who came through the program and placed the data in the public domain every two weeks—"almost in real time." This was accelerated by stimulus funds from the ARRA.

Finding an Unanticipated Innovation

When his group first showed their paper, fully characterizing the brain disease, they reported a few unanticipated "innovations": a possible resistance mechanism inside this disease, discernible only because they were able to review 400 to 500 patient samples. That became a reference set, in 2009, and other investigators compared it to their own data sets. They were able to find in their own groups patients who could perhaps be non-responders to aggressive therapy, thereby excluding them from therapies that wouldn't help them, and in fact would diminish their quality of life. Most recently, in the brain cancer data set, a new subset had been detected in younger patients; preliminary evidence showed it is possible to better predict the outcomes for this set of patients.

To capitalize on this ability the center was about to launch the Cancer Target Discovery and Development Network ($CTD^{2)}$ to link the cancer genomics they had seen and some existing therapies. The hope, he said—"which was something new"—was that some existing drugs that worked well on some patients could now benefit other patients. "Most important, we will share the analysis, tools, and data in real-time fashion."

As they gathered data about genes, they asked themselves whether they could do the same with proteins. The answer, from colleagues at the National Academies, was "not yet"—that proteins were not quite ready. "Because of variability in platforms; lack of standards, protocols, and reference data; and no consensus on how to report raw data, proteomic technologies were not yet mature," he said. So in 2005, the center launched a pilot project called the Clinical Proteomics Technologies for Cancer (CPTAC)—not to bring it to the clinic, but to prepare it for clinic use. Among its accomplishments to date are the first demonstration that MRM (multiple-reaction monitoring) is highly reproducible across multiple laboratories and technology platforms. The center also developed a public data portal for all the individual raw data points so people could share their data. Some unanticipated innovations were (1) a joint development with the FDA of a mock document that would allow a new generation of developers to move more easily through this regulatory boundary, and (2) ability to establish an antibody characterization laboratory that provides high-quality reagents at low cost to the community, posts all characterization data on a public database, and links with industry partners.

As of the previous day (in summer 2011) the center launched Phase 2 of CPTC, using the exact specimens that went through the genomics program and analyzing the proteins of the very same specimens. This data set will also be available on line in real time.

Bringing Nanotechnology to Clinical Oncology

Meanwhile, the center had begun looking for ways to combine the power of nanotechnology with this new perspective. "We kept thinking, could we harness some of this disruptive innovation for clinical oncology." The great promise of nanotechnology was to use tiny sensors and imaging to detect disease before health has deteriorated, to deliver therapeutics with improved accuracy and efficacy, and develop research tools to enhance understanding of the disease.

In 2004 the center published the first nanotech plan solely directed at clinical utility. Others had used nanotech for basic biology, "but this one was different." In the first phase, launched in 2007, the center was able to develop about 50 companies through SBIR awards and other mechanisms, file over 200 patents, and start eight to 10 clinical trials from the nanoplatform. In January 2011 they launched their first clinical trial that uses the nanoplatform to diagnose the patient, as well as a nanotherapy to deliver a gene-targeted therapy. The program has now entered its second phase.

Reaching Out to the Physicists

In conclusion, the center has produced a great deal of quantitative and reproducible data at the macroscale, microscale, and finally the nanoscale. The goal now is "to do something more complex; to really understand the system, and try to predict it using all this new data. We thought the best way to do that is to bring in another point of view, and when it's a hard problem, we always turn to the physicists." They recruited some 300 extramural physicists to attend three workshops in 2008, and found high interest in looking at this problem differently. The center started a network called the Physical Sciences Oncology Network.

"They came to us and said, you draw these beautiful diagrams of how the signaling networks work, but you never show us what actually happens in time and space; how things move around; how they are subjected to physical laws and forces." We showed them how we think about metastases, and "they said it may look more like this. They helped us look at it differently: to generate new knowledge, and catalyze new fields of study by utilizing physical sciences and engineering principles to enable a better understanding of cancer and its behavior at all scales. We were not looking for new tools to do 'better' science, but new perspectives to do paradigm shifting science that will lead to exponential progress against cancer."

Dr. Lee said that the center does have German physicists in its network, and always hopes to do science internationally. The network itself is designed to be open and receptive to collaboration and trans-disciplinary teams.

"What we are trying to do," he concluded, "is to build the infrastructure that can better understand and control cancer through the convergence of

physical sciences and cancer biology. We envision a future where individualized medicine becomes a reality—individualized, targeted cancer care."

MEDICAL/BIOMEDICAL INNOVATION FOR THE 21ST CENTURY

Joachim Giesekus
Strategic Marketing, Fraunhofer Heinrich Hertz Institute (HHI)

Dr. Giesekus introduced himself as a mechanical engineer who had worked for a few years as a researcher in industry before returning to Fraunhofer. His institute, he said, has collaborations worldwide throughout the broad field of information and communications technology (ICT). A central objective is to extend the institute's expertise in traditional telecommunications to new business sectors, including biomedicine.

The HHI was founded in 1928 to do research in telegraph and telephone engineering. It expanded after the war, and by 2003 was ready for a new phase of development as it joined the Fraunhofer organization. "Since then, he said, "we have had to focus much more on marketing and earning a proportion of our budget from industry contracts." One of HHI's successes has been development of the video coding standard H. 264, which is comparable in importance to the MP3 coding standard developed for audio. H. 264 is the basic coding for HDTV, Blue Ray, and other video standards, and is used by YouTube, iTunes Store, Adobe Flash Player, Microsoft Silverlight, and other streaming Internet sources.

Medical Uses for Information Technologies

With some 400 employees, HHI works in almost every corner of the ICT sector, including multimedia, data processing, image processing, interactive media, photonics, sensors, and data networks. When it became a Fraunhofer institute and shifted toward marketing, its researchers discovered "some raw diamonds that needed only some polishing to move technologies we already had into market. This talk is about how we get basic research results into the market for the medical device industry."

For the past decade, for example, the institute has studied an ultra stereoscopic 3D display that can be used without eyeglasses. It depends on the ability of the display screen to detect the position of each eye and alter the pixels on the display accordingly; this allows the eyes to perceive a large "sweet spot" and optimal depth "This is something we can use to show a patient an image in the field of medicine."

In a second example, the HHI collaborates with the Berlin Philharmonic and an automotive industry partner to create immersive media platform with high resolution audio, video, and 3D. This makes use of their own cinema technology, which "has the highest resolution world-wide." It is already

used for sports events, and HHI is planning to extend it to augmented reality and medical applications.

Another technology developed in combination with high-resolution video and augmented reality is "touchless pixel-precise 2D or 3D real-time tracking." Almost like a shadow puppeteer, the user's stretched-out fingers can control and even manipulate various images without touching them. A surgeon would be able to directly control the content of a display by simply pointing in a sterile environment. HHI worked with a medical equipment company to market its technology to clinics and hospitals.

Another example where video processing plays a large role is 3D image processing for biometrics. Usually 3D video has to go through a period of post-processing, which makes it difficult to use in real-time medical applications. From its long experience creating 3D information from 2D video, HHI is able to use multiple cameras to create perfect stereo impressions in real time, which is useful in many medical applications.

The same HHI department, using the same algorithms, has produced a "virtual mirror." He described a young woman wearing a green shirt, looking into the mirror; as she looks, the color of the shirt changes; then the colors of nearby art-work change as well. For medical application, such a technology could be used to display a surface such as the outside of the liver; a change in liver health can then be displayed as a different color to aid diagnosis or research.

A Technology to Detect Both Plagiarism and Cancer Cells

The HHI has been working for many years on a technology that detects plagiarism, either on the Internet, with IP, or elsewhere. They are able to detect similar pictures, or sift through a huge set of pictures to find the same cars, people, or other defining "fingerprint." Such a technology might be applied to cancer detection, said Dr. Giesekus, if the algorithm can be used to identify tell-tale cancer indicators in a patient's cells.

The HHI is also working on a medical application of a technology that stabilizes video processing. Researchers have developed a core technology of high dynamic range (HDR) video that, like Photoshop, can recalculate the light or dark qualities of a picture. A problem in applying the same technology to video, he said, is that the dark and the light pictures are not taken at precisely the same time, so motion distorts the image. HHI engineers have learned to eliminate the motion, a technique that could be used to stabilize the images of an endoscopic procedure or other operation in the body.

Dr. Giesekus mentioned several other technologies with possible medical applications, including optical sensing at the nanoscale to identify dangerous bacteria or explosives; tiny fiber sensors, now used to measure stress and strain in a building, to control the position of a colonoscope or other instrument; cheap, handheld terahertz imaging devices to detect cancers, cavities in teeth, explosives, or other abnormalities.

"Our wish now with this technology is to find more partners in the fields of research that can use our technology," he concluded. For this reason, HHI opened a new office in Boston in 2011. "We are always looking for industry partners and research institutes," he said, "where our technology from telecommunications can be applied to other uses."

DISCUSSION

Ambassador Murphy asked the speakers how they were able to select new areas for application of existing technologies. Dr. Lee said that his initiative was now known as "physical sciences oncology," and this had opened the door to mathematicians, computational scientists, and others. "The network itself is very open," he said. "There are pilot funds that the centers themselves solicit, so we ask them to be innovative clusters on their own. They bring in new people and new ideas. We have a grand challenge where all 12 centers work together to bring in a grand challenge and new expertise as well." Dr. Giesekus said that in the HHI, almost all the scientists are physicists, with backgrounds in telecom. These people, he said, "are our core knowledge. Now we are looking for new applications, so we need collaboration. So we bring together a few research institutions, and a few companies, and the company keeps us on track because it has to earn money. So the Fraunhofer model keeps our eye on market solutions, while the solutions need the science to be successful."

Panel X

Policies and Programs to Build Solar Industries

Moderator:
Peter Strunk
WISTA Management GmbH
and
Adlershof Science Park, Berlin

As moderator of the last panel, Mr. Strunk turned to a topic of both German and American expertise, the solar energy industry and its policies and programs. He introduced the speakers, Dr. Neuhoff and Dr. Le, noting their own considerable expertise from which to describe the German and American experiences in solar energy.

THE GERMAN SOLAR INDUSTRY

Karsten Neuhoff
Director
Climate Policy Initiative (CPI-Berlin)[42]

Dr. Neuhoff said he had recently joined the Climate Policy Initiative, a new global network with offices in Berlin, Beijing, and San Francisco, that has the goal of assessing the implementation of climate policies in different regions of the world.

He said he would discuss photovoltaics as a central strategy in climate policy, and look more closely at policy differences in German, China, and the United States. With current crystalline silicon technology, he said, rooftop-scale PV could produce about one-fourth of all German electricity, and about ¼ of all Chinese electricity by 2020, assuming demand continues its current growth. With more efficient cells, or solar collections at larger than rooftop scale, that amount could be increased.

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[42]Dr. Neuhoff presented his work in partnership with Molin Huo and Thilo Grau.

Currently, he said, three PV technologies are competing for market share. The crystalline path has traditionally led in market share, although thin film technology seemed more promising technology for the last two or three years. Over the last six to nine months, however, crystalline technology has regained its lead in terms of cost competitiveness and is "probably going to be back up to 80 to 90 percent of global demand." The third area is multi-junction technology, which is more efficient but more expensive, and also needs a structure that tracks the sun's position, further increasing cost.

Therefore, Dr. Neuhoff said, he would focus on crystalline technology. The cost of producing PV electricity depends first on insolation. Some eastern provinces and southern provinces receive up to 1100 kilowatt-hours of sun averaged over the year and can produce electricity for about 30 euro cents per kilowatt hour. A major factor in cost, however, is the cost of capital, which needs to be near 4 percent or less. For large-scale application, he said, overall costs need to be reduced by a factor of two before solar can effectively compete with current electricity prices in Germany. Obviously, however, once the PV penetration is very high, storage facilities must be built to stabilize electricity supply, which brings additional cost increases.

In China, which has more sunshine, especially in the southern provinces, solar technology looks more attractive. To some extent, deployment costs are also high, but the break-even point against which the technology is competing is lower, especially because the costs of carbon are not built into electricity pricing.

Dr. Neuhoff turned to the 15-year trend in the price of roof-top systems in Germany. After 2000 came a gradual reduction until about 2006 to 2007. The reduction has accelerated since then, as a result of three drivers. One was the opening of the German market to international competition. "As long as we had a German-only market on both demand and supply sides, there wasn't much pressure on companies to innovate or improve competitiveness. You could actually observe all the actors in the value chain reaching their margins." Second were several certain production scarcities, such as a sudden drop in the silicon supply, which brought a high price for a time. Finally, several innovations contributed to recent cost reductions.

For this symposium, he said, he would look at five kinds of innovations that could bring such cost reductions. One of the biggest kinds of innovation was that of the U.S. company, First Solar, which introduced a new commercial thin film cell of cadmium telluride in 2003. Building the cell required about 15 years of public support through universities and national laboratories. The company made all its decisions internally and maintained ownership of their technology longer than do most companies. It remains one of the biggest producers globally, with much of its production capacity in China. What drove much of the company's growth, including private investment, was the expectation of a future market, and indeed, the market in Germany, and then briefly Spain and Italy, were major causes of growing global demand. All three were driven by

government incentives, especially feed-in tariffs that guaranteed utility buy-backs of PV-generated electricity.

The second innovation was a set of technological advances that increased PV efficiency from 17 to about 19 percent in crystalline cells. Behind this progress, he said, was companies' understanding of the production process of the entire cell, and good links or even internal lines between the module components and wafer components. "You have to make adjustments across this entire process when you introduce a big innovation into the technology. If you look at the industry structure, both in Germany and China, you see quite a few companies that were able to do this."

A third behavior that has been helpful is that many of these companies were competing "in parallel," or seeking to innovate in the same areas. When one company succeeded in perfecting a technology, the others were able to adopt it quickly, benefiting the industry as a whole.

The fourth set of innovations was the arrival of new expertise in the PV industry. For example, Dr. Neuhoff said, Applied Materials bought Varian Semiconductor Equipment Associates in May 2011 for $4.5 billion. One of the stated goals for Applied Materials, a major equipment supplier in PV, was to gain access to the new technology of ion implantation, which was not yet used in the PV area. Such buying of companies to gain new technology increased the efficiency of the final products, and therefore of PV.

Finally, over the past two years, equipment supply companies had entered the PV arena, which had traditionally been dominated by the solar cell manufacturers. For example, cell producers had been experimenting with the use of selective emitter cells in solar arrays without notable success. Suddenly, two large global equipment suppliers, Gebrüder Schmidt, followed quickly by Centrothem, developed equipment of their own to produce selective emitter cells. They soon found an Asian partner willing to take some risk in adjusting the production process for this change, and in exchange the Asians—a and the industry—has an innovative technology a few percent more efficient.

Dr. Neuhoff said that some cost reductions over the last two years were also generated by moving production to China, where input materials are cheaper. At the same time, innovations to the input materials, especially the pads used to fasten the conductors to the wafer cell, have brought higher quality. "They have become better," he said, "so you can make the cells thinner, you lose less light, and you have better contact between materials."

Some challenges have emerged as well, he said. Previously, demand effectively created incentives to select different technologies and invest in those with highest efficiencies and lowest cell costs. Now, for both the United States and Germany, the cost of modules has come down to the extent that the installation and system integration costs of PV account for less than half the total cost of the PV. And yet, he said, the costs of putting a PV panel on the roof are still significantly higher in the United States than in Germany.

One implication of this changing cost structure, Dr. Neuhoff said, it that it is very difficult to anticipate what it will cost to install a PV panel. "If you

don't know what the cost will be," he said, "it is difficult to anticipate demand by offering a fixed price." Germany now has a lot of capacity to install PV panels, he said, both on the roof and on also a large scale, and as a result, PV demand has picked up more quickly than anticipated. This is enhanced by the global fall in PV prices. As a result, the PV support level in Germany was reduced over the last year. Weekly deployment volumes in Germany rose in anticipation of this price reduction as many households decided to deploy panels quickly. Thus, deployment has become more sensitive to the level of the feed-in tariff because the consumers respond more quickly.

Italy experienced this even more dramatically, he said, because its tariff was rather generous, and when the tariff rose, many German installing companies were driving to Italy to build PV panels. "Using the feed-in tariff offers you low capital costs," he said, "but the technology is now small scale and established enough that we need to be quicker in adjusting it and careful in the implementation. It's an effective but tricky instrument."

One large benefit established in Europe, Dr. Neuhoff said, is the renewable energy trajectories, by which countries commit to the EC to follow a certain trajectory for the technology they want to develop in coming years. This provides a guideline against which countries can adjust their tariffs over time. "This year we are discussing whether to adjust the feed-in tariff according to the market price almost week by week."

A second big challenge, he said, is the balance between supply and demand. The global supply, or production volume, was 15 Gw in 2010, while installed capacity is now between 30 and 40 Gw. This is a setting, he said, "where, for a capital intensive industry, you might be concerned about boom and bust."

To some extent, Dr. Neuhoff said, the 40 Gw number is high, because it includes some old capacity and some that could operate only at peaking load. "But the number is still an important indicator over the next 12 months. If the market senses a lot of excess capacity, and investors start to feel uncomfortable, we need to know how that is going to impact the confidence of investors and innovators. If cash flows are restricted, what happens to innovation? Where are companies going to cut first? On the other hand, some excess supply creates incentives to reduce costs and helps choose the best technologies."

Another challenge, he said, was to apportion public support among three needs: early-stage R&D, where much innovation arises; manufacturing, which is desirable in generating employment and stimulating R&D; and support for demand and "putting panels on the roof." One goal is to allow the private sector to identify the most promising innovative activities. He noted the earlier discussion in favor of supporting battery manufacturers, saying that too much support makes it difficult to design incentives for innovating and selecting the best technologies. He said that over the last two years, countries provided much higher subsidies for deployment than for manufacturing. "I think there will be increasing understanding among countries that it is unfair to support only manufacturers, and that this must be balanced by support for demand."

Dr. Neuhoff summarized by saying that many innovations, certainly for crystalline PV, had been possible only because of strong innovation networks, which allowed ideas to be integrated into existing production processes. This led to gradual learning by doing, innovations in efficiency, and cost effectiveness. "We don't know which innovations over the next five years will help us make a technology twice as good as it is today," he said. "But we certainly should create an environment that maintains opportunities." One important part of the environment, he said, is transparency, especially as more government programs are created. This is necessary both to protect government against supporting the wrong technologies, thereby forgoing new opportunities, and to let countries learn from one another which technologies are most effective.

Dr. Neuhoff concluded that "it's the market pull that has driven this technology, and has attracted a lot of talent and technology companies into this field. Let's maintain this 'pull policy' by having more commitments of government to advanced deployment policies. That strengthens confidence, and is going to be crucial in this imbalance of supply and demand. Government has a role to reassure investors that there's going to be growing demand over the next three to four years. This demand is still going to be policy driven before the technology is cost-competitive at the wholesale level."

U.S. INITIATIVES IN SOLAR ENERGY POLICY

Minh Le
Chief Engineer, Solar Energy Technologies Program
U.S. Department of Energy

Dr. Le began with a familiar comparison of the solar energy available to the United States and to Germany. The United States, he said, receives about as much insolation as Spain, a notoriously sunny nation. The U.S. state receiving the lowest insolation is Alaska—which receives approximately the same amount of solar energy as Germany. And yet Germany, dark though it is, generates about half of world demand for solar energy.

There are grounds for hope, however, in U.S. demand. In 2010, he said, the United States installed approximately 900 Mw worth of photovoltaics (PV), about a 100 percent increase over the prior year. Projections suggest that that growth will continue, and by 2013 or 2014 may actually exceed demand in Germany.

The United States employs 65,000 to 95,000 people in the solar sector, while Germany employs about 120,000. In the amount of solar installed unit per land area, or solar per capita, however, the United States lags Germany by a factor of 20 to 30.

Dr. Le reviewed the policy tools that influence demand and supply. On the technology push side, he said, the United States uses R&D funding for new technologies, R&D tax credits, and manufacturing tax credits. One example is the solar incubator program run by the National Renewable Energy Laboratory

(NREL), which since 2007 had funded 24 PV startups with an aggregate value of about $59 million. Those 24 companies had leveraged about $1.3 billion in private capital, and employed more than 1,200 people. "We funded some of these when they were as small as two people," he recalled some now have 300 to 500 employees. Against these successes were other companies that did not succeed, although he said that shutting a firm down can be seen as a positive in freeing up capital, both human and financial, from a technology that was not able to mature.

Tools for the deployment of PV, he said, include feed-in tariffs, renewable portfolio standards (RPS), investment tax credits, loans, loan guarantees, and other financial mechanisms to lower the cost of capital, as well as depreciation tools that are modified for tax purposes.

Unlike Germany, he said, the United States relies heavily on the R&D investment tax credit of 30 percent. Germany relies primarily on the national feed-in tariff. Many secondary support mechanisms for both manufacturing and demand are fairly similar in the two nations.

The German feed-in tariff, Dr. Le said, had proven to be a "tremendous market pool mechanism that has been able to increase demand in the marketplace. It can also create some high peaks in demand, and is expensive to the ratepayer, though not to the taxpayer. The German FIT cost roughly 4.6 billion Euros in 2009, and a little more in 2010, representing 0.2 percent of GDP. If we deployed capital at that level in the United States, it would total about $30 billion."[43]

While there is no national FIT in the United States, a number of states already have them, or are studying them; so are some municipalities, including Sacramento, San Antonio, and Gainesville, Florida. "A FIT at the national level would be difficult," he said, "because of regulatory hurdles at state and local levels."

The favored mechanism to incentivize demand in the United States is the renewable portfolio standards (RPS), which have been adopted or planned by 30 states. A significant fraction have solar carve-outs, or solar-specific renewable standards. This creates markets for renewable energy credits, or solar renewable energy credits, which in turn stimulates demand.

The primary national incentive structure is the investment tax credit (ITC), which automatically adjusts as price declines. On the negative side, one needs a "tax appetite" to take advantage of the ITC, as well as up-front capital. The lack of long-term clarity can be a problem, as the ITC is set to expire in

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[43]Germany launched the era of the feed-in tariff (FIT) in 1990. The FIT requires utilities to purchase electricity generated from renewable sources at prices a percentage of the prevailing retail price of electricity. The law was revised in 2000 to guarantee purchase prices for 20 years, allow utilities to participate, and reduce costs annually based on expected cost reductions. Because the FIT sets rates based on cost of production, wind power producers receive lower rates, for example, than PV producers.

2016. In Germany, the FIT is both stable and simple—two features that encourage investors and allow capital to deploy widely. The negative aspect is the cost to the ratepayer, but many are willing to bear it.

The two nations are similar in government funding for solar R&D as a percentage of GDP. For the United States, the ARRA, passed in 2009, was a very important policy tool to spur deployment of manufacturing and renewable energy technologies. One such tool was the grant in lieu of tax credits. Unlike the ITC, which requires a tax appetite and does not provide payment until taxes have been paid, the grant in lieu of tax credit provides the money up front.[44] Wind energy, in particular, has been able to benefit, receiving $5.2 billion that enabled it to expand in the United States. Wind represented some 40 percent of new generation capacity in the United States in 2010. Solar received about $600 million from that program.

The more significant stimulus for solar has been the advanced manufacturing tax credit.[45] Manufacturers of polysilicon thin film receive about half of the $2.3 billion in the solar program, with other technologies receiving less. Similarly, the loan guarantee program has been a crucial part of the U.S. portfolio for the deployment of solar energy. Of the $10.7 billion conditionally committed or finalized in loans, $8.3 billion went to the solar sector in 2010 for deployment and manufacturing. Some of the larger grants went to utility-scale solar farms, PV or solar manufacturers, and concentrating solar power (CSP) research.

While these programs are helpful, Dr. Le said, they are not sustainable. "The private sector needs to take over if this sector is to expand," he said. The total amount of VC and private equity financing deals in 2010, he said, totaled about $2.3 billion. Roughly ¾ of those deals were done in the United States, which has a very strong VC community that has been an engine for innovation. This is an important first link of that value chain, he said, but it is not sufficient. "Debt financing and asset financing is what will be required for this industry to expand much more widely than it is today." Of the $44 billion in solar debt financing world-wide in 2010, the United States held only a 9 percent market share. "That isn't much," he said.

Dr. Le then showed a graph that reflected "a sad state of affairs." In 1995, the United States produced 43 percent of PV cells and modules world-wide. "Admittedly the industry was a lot smaller. But over the course of the next 15 years, U.S. market share eroded, and in 2010 the United States held only 7 percent of world market share. "Most stark is the growth of PV cells and modules produced in China and Taiwan. Rising from almost nothing in five years, they have captured almost 60 percent of the worldwide market share in a short period. This speaks to the erosion of our manufacturing competitiveness."

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[44]The grant in lieu of tax is described in section 1603 of the National Tax Code.
[45]The ITC is found in Section 48C of the National Tax Code.

He referred to a point made by Andrew Grove, a co-founded of Intel, who said that abandoning today's manufacturing can "lock you out of tomorrow's emerging industries." To the degree that a country's manufacturing sector declines, so does its ability to innovate. This was one perspective that helped shaped the innovation policies of the Obama administration, which was trying to use the interplay between solar research and solar production to make the technology cost-competitive with fossil fuels—and to do that without subsidies. "If we can," he said, "solar will be deployed across the United States—not just the West, but across Maine, Michigan, North Dakota. These are exciting and audacious challenges. But please know they are not easy: they mean a 75 percent reduction in cost."

Dr. Le said that the United States can draw inspiration from other countries. In the United States, the cost of residential solar installation was approximately $6.50 a watt in 2010. In Germany, it was approximately $3.80 a watt. "Given that the cost of PV modules is the same worldwide," he said, "what's really different is the balance of systems, especially installation and permitting costs." These can be widely different in two cities in same state. Lowering such high costs and removing cost inequities are administration priorities, he said.

In conclusion, Dr. Le said, government policies can accelerate clean energy "at speed and at scale." The German FIT had been a very effective tool to help spur the solar industry, and had resulted in global solar leadership on the demand side. The United States has a hybrid mixture of federal, state, and local incentives to spur not just demand, but also supply. "This is an exciting time to work in solar. If we can reduce solar costs by a factor of three or four by the end of the decade we can play an important part in meeting president Obama's clean electricity standard of 80 percent by 2035."

DISCUSSION

Mr. Strunk noted that the U.S. picture had long been characterized by the availability of "cheap oil and many natural resources." In Germany, he said, the picture was quite different, and the need for alternatives much greater. He asked, "Does this in your opinion highly influence the ambitious program to advance solar energy in Germany, with the result that we are far ahead?"

Dr. Le said that with trillions of dollars of assets already deployed in the U.S. energy sector, change "does not happen rapidly; there's also an incumbency you have to overcome. It will take time. But if we don't start, we'll never get there. So we have to start working on all those challenges."

Dr. Neuhoff agreed, adding that while "energy security" is commonly emphasized in the United States, "in the end it's the political economy of incumbent groups that want to maintain their position investment. So it's about creating a dynamic where new technologies have bigger expectations and representation in the political process, and then gather support from the voters."

A questioner asked why Germany, despite its large demand pool, was not spending more on R&D. Dr. Neuhoff agreed that until about three years ago the solar industry did have a low level of R&D spending. Recently, however, he said that the pace of R&D seems to have increased, in both public and private programs, because "international competition really created the moment when they realized they had to increase cost competitiveness."

Dr. Wessner asked about the common view that "the United States is doing the research, the Germans are installing, and the Chinese are producing." Dr. Le said that view no longer seemed to be justified, with function in the United States coming into balance. "In the United States, by about a year ago, we installed about as much solar panel capacity as we produced domestically. So we have a fairly even one-to-one production vs. installation."

Dr. Neuhoff said that indeed the picture is mixed. Much of the research in Germany is dedicated to improving crystalline technologies, while much public R&D money in the United States goes to very new concepts, or "long shots." Also, much of the equipment used globally to produce PV cells is still produced in Germany, "so while you usually see how many PV modules we import from China, you rarely see how much equipment is being sold to China to build those modules. China has a lot of interest in manufacturing more of its own equipment, but at the moment but it appears to be almost a balanced picture."

A questioner asked about the roles of transmission and storage.
Dr. Le said that they would both become more important as solar and other renewables provide a greater fraction of electricity to the grid. "In the United States now, however, solar represents roughly 2 percent of our electric generation capacity, while in Germany it's about 10 times as much. We are investing in solar thermal technologies, which have inherent storage capabilities, and that will be an important portion of our grid."

A questioner asked how a government in an era of fiscal stringency could justify putting public dollars in an industry where capacity is twice as great as demand.
Dr. Le replied that "if you don't make the investments today, you will certainly not be in the game tomorrow. As a taxpayer I believe you need to make certain investments that will enable a prosperous future." Dr. Neuhoff agree that it was "quite a challenge to build up capacity," but that if Germany were to stop its support programs, financial participants would also stop their support, "and within a few months we would have cash flow issues across the sector. We would lose a lot of the capacity that was carefully built up and that might contribute both to global PV development and to German economic success. You need to maintain the momentum if you want to play in the game."

A participant who worked in Adlershof Science Park in Berlin addressed the wisdom of innovation subsidies, which can be both "right and wrong, and a paradox. Sometimes it's a necessity to build up new technologies with subsidies in the process of long-term planning. It took us about 15 years to

develop this solar industry. Meanwhile we have a company producing thin-film solar panels and exporting them to China—not the other way around."

Dr. Prabhakar agreed that Germany had been "extremely effective" in translating R&D into deployment, and in making Germany a global leader. She asked whether the progress of solar had been "out of proportion to what Germany would like to accomplish with other renewable energy sources, and whether the country had paid too high a price to achieve its huge solar leap forward. Would you do it again or are there better ways to get to this point?"

Dr. Neuhoff said that the technology costs had fallen more quickly than most people had expected, and that was the important goal. When he began working on PV in 2005, he said, the "perspective was that wind was close to cost-effective, so why would we want to go into solar?" He said that in terms of storage, "it's going to be valuable for the German system to have a set of different renewable technologies. Storage requirements decline faster as the portfolio of technologies becomes more diverse." He conceded that if one now took a long view of the renewable system, solar could have been built "a bit slower, but at the end, it won't really matter by 2030." He said that the investment costs have been high, but "in the end we've succeeded in developing the technology. He said that the German progress had also inspired China to raise its goals for solar deployment from 5 Gw by 2015 to about 20 Gw by 2020, which created a general good. "So yes, sometimes you have a make a first step; you might benefit yourself, but also contributed quite a bit to development elsewhere."

A questioner asked whether thin film, a hot technology a year previously, was "a little bit of a has-been" with the drop in price of crystalline technology. Dr. Le said that for the U.S. Government, "the official answer is that we're technology agnostic. We set goals for technology to achieve in terms of performance and cost, and technologies that achieve those goals will be deployed widely. We're not trying to pick winners." At the same time, he said, the DoE follows every energy market, and makes investments in all promising technologies, including crystalline silicon and thin films. He said he was personally optimistic about thin film, "and there are good reasons to be optimistic about some of these new technologies."

A questioner asked whether Germany had invested too much money in a technology that was not very efficient in generating electricity and "which seems to be a niche technology at best?" Dr. Neuhoff admitted that the PV technology did require more improvement in efficiency and cost, but that "if we want to decarbonize our power sector, which is a stated goal across Europe, it's difficult to do this with individual technologies. It really takes a portfolio of them. Why not use the opportunities to have PV across our roof spaces? I think it is in the cost range where it's going to be viable, and it provides about a quarter of the electrical power for Germany."

Dr. Le added that from a technology standpoint, "there is a still a significant gap between what our 'hero cells' can achieve in the laboratory, and what those cells could theoretically achieve from basic physics' first principles,

and a bigger gap between those cells and what our manufacturing lines can achieve day in and day out. There are opportunities in both places to improve performance."

Mr. Strunk asked what would be next step in dealing with alternative energies—"not just solar or wind, but integrating systems, including storage. Would storage allow the renewable energies to have a final breakthrough?"
Dr. Le said that a number of breakthroughs will be required—not just technology, transmission, and storage of electricity—but also financial. "This is a capital-intensive industry," he said. "We need finance mechanisms that will enable industry to expand."
Dr. Neuhoff added that "we are in the middle of a transformation. It is reassuring that we don't have to wait for one big decision from government, because these issues are difficult to deal with in commercial environments. It's really about gradually evolving the system, and I think we are in a world where we can learn from each other in this process."

"In Germany now," he continued, "we have the revision of the renewable energy law, which happens every two years, and we anticipate a move from the feed-in system to a system that offers a premium to sell the electricity in the market. I think the discussion behind this decision was a bit too narrow, because we want to open the electricity market to different technologies. I don't think we need to adjust the feed-in tariff for this purpose; that would make it more complicated and therefore risk misbalancing it. What we need is to change the power market so it is open to other technologies. The United States has experimented for years, but now has established the renewable portfolio standard that has spread across the liberalized markets and is demonstrated to be effective. So let's learn from each other and adopt another system which is established, well practiced, and tried out."

Roundtable

Energy Change: What Are the Consequences for the German and U.S. Innovation Systems?

Chair:
Tim Stuchtey
Director, Brandenburgisches Institut für Gessellschaft und Sicherheit

Seth Winnick, Counselor for Economic Affairs, Embassy of the United States

Sylvia Kotting-Uhl, Green Party; Member, Committee for Education, Research, and Technology Assessment

Albert Rupprecht (CSU) Committee for Education, Research, and Technology

Ernst Dieter Rossman, Social Democratic Party, Schleswig-Holstein (SPD); Member, Committee for Research, Education, and Technology

Arati Prabhakar, Partner, U.S. Venture Partners

Mr. Stuchtey introduced the members of the roundtable, who included two representatives of the German Bundestag, and noted that for this session speakers would be using their native language. He gave a brief summary of the topics discussed during the two-day workshop, and asked Mr. Winnick to begin.

SETH WINNICK

Mr. Winnick began by noting that energy policy is an area "ripe for innovation," and where innovation will "very much drive what happens over the next years and decades."

His first observation was that the United States and Germany share similar goals, but approach them from different perspectives. A shared goal is to "make a transition to a low-carbon economy and society." The approaches differ

in areas such as risk, risk management, tax policy, incentives to renewal energy, and application of federalism to national energy policy.

For example, while there is heightened concern with U.S. security following the Japanese nuclear disaster at Fukushima, "there is every intention to not only continue operation of the existing nuclear fleet, but also to resume construction of new plants." The first two plants are nearing the beginning of construction, and others are seeking approval. Research also proceeds on nuclear reactor technologies, including thorium-fueled reactors and mini-reactors.

In terms of energy efficiency and controlling emissions, he continued, Germany has relied on market-based mechanisms, especially the feed-in tariff system to promote solar energy, and the aggressive use of tax policy and gasoline taxes to incentivize efficiency. "I find it ironic that the United States, which believes in market forces above all else and opposes regulation, uses regulatory tools for energy efficiency and emissions." For example, he said, the mandated corporate average fuel economy (CAFÉ) standard is the key instrument in reducing fuel usage in transportation. Heavy taxation of gasoline to foster conservation is not politically acceptable, he said.

Similarly, while Germany has promoted increased use of renewables done through a market mechanism, the feed-in tariff, while the United States has used what is basically a regulatory approach—but at the state level. More than half the states have mandated that a percentage of energy consumption must be produced by renewables by a specific date, varying from 5 to 40 percent or even higher. For example, California, one of the most aggressive states, requires that 1/3 of its electricity be produced by renewables by 2030. "So if Germany is disappointed in the U.S. Congress for not passing a comprehensive climate bill," he said, "there is at least extensive action at the state, local, and also corporate levels."

His second observation was that the degree of U.S.-German cooperation in science and technology is "huge." Each heavily invests in the other's energy systems, he said, as well as research, development, and innovation. He gave "representative examples" in both directions, with Siemens and E.ON investing in wind energy in the United States, and First Solar Arizona making a large investment in Frankfurt on der Oder. Solar World in Bonn has production facilities in the United States, and Sulfur Cell based in Berlin has received substantial investment from Intel Capital.

In research cooperation, the National Renewable Energy Laboratory (NREL) and three Helmholtz Association laboratories have agreed to conduct joint research in photovoltaics, solar cells, and concentrating solar power. Fraunhofer opened a center for Sustainable Energy Systems in Cambridge, Massachusetts, several years ago. Finally, he said, the two countries signed a "significant S&T cooperation agreement" in 2010, which will be implemented over several years. "So our S&T cooperation is a big story for innovation policy," he concluded, "and for our transformation to a low-carbon economy."

SYLVIA KOTTING-UHL

Mr. Stuchtey turned to Mrs. Kotting-Uhl, and asked about the implications of Germany's decision to abandon nuclear energy. "What impact will this have on our research, development, and innovation system here in Germany?"

Mrs. Kotting-Uhl said that the trend away from nuclear power was at least a decade old, and that the events in Fukushima had only strengthened the Greens' belief that "the nuclear phase-out was, and remains, the correct path." She said that because she is "primarily an environmental and energy politician," for her the "biggest task before civilized and highly industrialized societies is to stop climate change. This means that the goals dictated by climate change are the ones we need to focus on; they're the ones indicating where research is primarily needed."

Whether nuclear energy is part of this mix or not, she said, a conversion of the energy system toward renewables is essential. "This requires much research," she said: "How are we going develop storage technologies? Electric mobility? Other ideas are larger renewables power plants, large power storage ability, perhaps even storage power plants in Norway. There are many ideas and I think a lot of money should be directed toward them."

She added that it was wrong to bet on nuclear projects, including nuclear fusion. "The energy system that we need for 2050 is an energy system that shows we have learned to handle precious energy with great awareness, and sparingly, without lowering our quality of life, but in an economic and efficient way."

In terms of climate, she said that by 2050 the country should be converted 100 percent to renewable energy. "This means that we should already be laying the groundwork today. We can no longer afford to do any non-application-oriented research regarding the 'great task.' That is, we must know what we need by 2050 and we must align our research accordingly."

By then, she said, nuclear fusion might just be coming into feasibility, but that to count on it "would mean counting on suddenly having loads of energy in 2050—and we won't need this amount of energy within the [more efficient] system we will have by then. So even if fusion worked, it won't be necessary at that time. This is why I am of the opinion that it is a waste of research energy and money. I think we will be well advised to focus all our energies on the system of decentralized, renewable energy with storage technologies, and networks."

She said that her conclusion was "to think from the point of view of the goal: what do we need in 2050? What is the great task we must fulfill? And what does this mean for the research funds and brains in which we're investing? On these issues, we cannot afford any detours or dead-end streets."

ALBERT RUPPRECHT

Mr. Stuchtey introduced Mr. Rupprecht, an economist and member of the CSU from Bavaria. He had served in the Bundestag since 2002 where he is a member of the Working Group on Education and Research. Mr. Stuchtey asked Mr. Rupprecht for his assessment of what the phase-out of nuclear power and the increasing role of renewables would mean for the innovation system in Germany.

Mr. Rupprecht offered to formulate the issue the other way: what abilities do we have to meet our goal of a renewable energy economy? In terms of research, he said, Germany is well positioned. Since the physicist Angela Merkel became Chancellor of Germany in 2005, he said, the budget available for research and education through the end of the current legislative period had grown by 74 percent. This is "historically unique, one-of-a-kind," he said, "and even in an international context remarkable." Some of the important areas affected by this increase, he said, were in the energy sector, and it is a point of emphasis of the High-Tech Strategy, as is the "sub-domain of electric mobility."

A continuing problem, he said, is the "lack of a systemic, overall view. We have many universities with high research standards and excellent results," he said, "but the research results don't flow into a systemic 'big picture.' I want to compare this to the financial crisis. If we hadn't had, during those times, institutions such the Federal Bank and EZB to monitor financial trends with a systemic overall view, the financial system would have collapsed altogether."

Currently, he said, Germany is trying to resolve "the great world question of climate change and energy by saying 'Yes' to this type of energy—yes to wind energy, no to nuclear energy, yes to biodiesel, and so on. But only by having a systemic approach will we move forward." He concluded that, on the whole, "Germany is very well positioned in the areas of research and innovation."

ERNST DIETER ROSSMAN

Mr. Stuchtey then called on Mr. Rossman, saying that while driving in Mr. Rossman's state, he had seen signs that read, "Stop CCS" [carbon capture and sequestration]. He asked whether CCS will be necessary, along with more coal-fired power plants, now that nuclear energy will be phased out.

Mr. Rossman noted Mrs. Kotting-Uhl's insistence that Germany "completely switch over to renewable energy—and that this is the first, second, and third priority." He said that the country does have multiple approaches to this goal, including research and innovation; market incentives, from the eco-tax to the promotion of renewable energy; and regulatory measures. "I believe that we need to make a greater effort" that will work only "when we have an energy policy consensus because this will make our research strategy more reliable over a longer period."

He raised the "critical question" of CCS, which is an EU-wide issue. Unlike America, he said, "with a quasi-half-continent of its own," Europe is very diverse, with the expectation that research facilities and equipment will be shared among countries. While there is currently nothing in legislation, he said, the SPD "is of the opinion that we should not exclude the possibility of conducting controlled research in the CCS area, but only research." This policy would reflect the perspective that "we shouldn't be moving toward making this energy conversion" because research could reveal that this is not a reliable way to move forward. What we do know very well, he said, is that in terms of savings and efficiency, "renewable energy can help us achieve the main objectives that we are setting for ourselves politically."

In terms of research, he addressed Mrs. Kotting-Uhl's assertion that Germany should only conduct applied research specifically related to renewables. There is an extensive system in place for fundamental research, he said, in the Max Planck Institutes and research universities. He questioned whether it is sensible to "completely step away" from fundamental research, including nuclear energy research. While the Greens desire and predict an energy system based solely on renewables in 2050, and would like to focus research on that system alone, "we don't want to eliminate all the options until we have come to a conclusive point with our energy research, both in regards to nuclear fusion and CCS. The Social Democratic Party, he said, preferred to support a broad portfolio of fundamental research "because we believe we should not exclude insights that can become important in a more distant future."

Mr. Stuchtey asked the speakers whether Germany should continue to do nuclear research in order to improve the safety of nuclear waste repositories, and whether such work would provide careers for young people in nuclear science.

Mrs. Kotting-Uhl said this was a dilemma, because a nuclear phase-out would require additional research on safety, and the reactors in operation would still run for another decade or more. She did agree that a nuclear career was no longer an attractive option for the long term, but hoped that young nuclear engineers would be able to transition to related fields. Mr. Rupprecht basically agreed, while Mr. Rossman emphasized the opportunity for Germany to gain expertise in matters of long-term waste management and safety. Mr. Stuchtey asked whether research reactors, too, would be closed, and whether this would impair many related branches of research, such as nuclear medicine. Mr. Rupprecht agreed that this work is necessary, and worried that too few scientists would pursue it.

ARATI PRABHAKAR

Mr. Stuchtey turned to Dr. Prabhakar and asked her, as a venture capitalist, whether she would now look more closely at Germany for new

investment ideas, or whether she would favor China or India, "where discussions are sometimes a little shorter than in this country."

Dr. Prabhakar said that China and India would certainly have to be included in a systems view of energy and environment. From the point of view of a VC and investor, she said, "the key question is always about the markets and where capital is being deployed. For that reason, Germany is a very important market for the VC sector to understand. "The work that's been done here to drive photovoltaics through FIT," she said, "has been a dramatic step forward. The vibrant activities from the research stage through deployment are very promising. But of course China is moving even more aggressively, creating the most rapidly developing market for clean energy technologies in the world. If you look today at venture investments, they are very cognizant of where those end markets are."

DISCUSSION

Mr. Stuchtey opened the floor for questions. Dr. Wessner noted several issues around Germany's decision to forego nuclear power, including whether Germany would (1) need to rely on the willingness of Russia to provide more natural gas, (2) need to buy electricity from France and other nuclear neighbors, and (3) be prevented from totally closing down nuclear power by the need to address continuing issues of waste and safety.

The Nuclear Phase-out

Mrs. Kotting-Uhl said that "these are not new arguments being used against us." Do we need nuclear power eight or fourteen years longer than the old nuclear phase-out, or can we do without it? she said. Should we use gas from Russia, or nuclear power from France? Germany currently had nine nuclear power plants, she said, along with orders and international contracts. "The bottom line is we are a full-time exporter of electricity, and from time to time, electricity importer. But the goal remains, she said, to switch to renewable energies as soon as possible."

The nuclear phase-out, she said, will depend both on how long society thinks is reasonable, and how quickly society learns to trust the alternatives. "My personal opinion is that the policy goals we set for ourselves, the ones we are very serious about, must sit just a tad above that which we consider realistic at the moment. That way it will exert a bit of pressure; otherwise there will be no innovation."

One kind of pressure, she said, was the Renewable Energies Act (EEG), an instrument that allowed renewable energy to enter the market by guaranteeing that producers of renewable electricity can sell their power at a profit. This triggered a boom, and generated "a great learning curve" for the public, introducing many new concepts, such as "photovoltaic."

"This really gave people a chance to enter the market," she said, "even though the technologies were not marketable initially because of the price. The technologies quickly became cheaper, and wind energy, for example, became marketable. A similar pressure exerted by a nuclear phase-out will bring about alternatives that much faster."

Imported Gas or Electricity?

Mr. Stuchtey followed up on Dr. Wessner's question about the reliability of imported gas, and "whether our freedom is curtailed when it comes to foreign policy or other strategic decisions."

Mr. Rupprecht agreed that it was crucial to weigh different objectives and risk factors; to understand dependencies and how to avoid them. He cited the example of a solar energy generator in North Africa distributing power to European networks. "Who would have thought, a year ago, that there would be so much instability in North Africa? And so I would advise everyone to apply the idea of risk diversification to energy."

Mr. Rossman agreed, citing the uncertainties generated in the United States by its dependency on the oil from the Gulf of Mexico, from Saudi Arabia, and elsewhere. "This is why the economic connection to Russia and its gas isn't reassuring, and why we are trying to steer Germany toward renewable, decentralized energies by 2050 in the most economical and efficient way. We social democrats are not specifically advocating for a 'shutting off' of the coal plants, but rather for a combination of coal and gas in the transition to 2050. If you fear such dependencies, the answer lies in renewable energy and decentralized, preferably regional energy production and supply."

Mr. Winnick commented that when a field is seen as "closed, in decline, or otherwise off limits, people don't go into it." He said that despite Germany's great technical capabilities in the nuclear sector, "it's hard to imagine a student who starts university next year deciding to go into nuclear engineering." In the same way, he said, the United States has had the benefit of European researchers in agricultural biotech moving abroad as the field gradually weakens in Europe.

The Problem of Disposing with Nuclear Reactors

Mrs. Kotting-Uhl agreed that those issues were indeed difficult. "We do have to face the problem of what to do with these nuclear reactors. We have not developed a strategy for breaking them down, dismantling them, and disposing of them. We have to take into account the costs and consequences of doing this, and subsequent problems, and the nuclear waste we will have to dispose of, without knowing how."

Mr. Rossman confessed that while the Green Party had been aware of such problems for some time, many in his own party were still learning of the need to dispose of nuclear reactors, and the desire to continue using radioactive

materials in medicine and many other fields. "The political direction and priority is to phase out the nuclear power energy supply, not to step out of the surrounding field of radioactivity, which is somewhat different. We should be reassured that Germany exercises strict control over the use of radioactive materials, and that its use is limited to a few fields, including travel, research, and healthcare."

Mr. Winnick said that the United States and Germany would have to deal with such problems in their own local ways, and that the partnership in trade would continue. "Products made in Germany that work will still be bought in the United States, and things made in the United States that work will probably continue to end up in Germany. I don't expect a sudden planting of biomass diesel fuel crops here in Europe, and even if we move to a FIT system, you probably won't see a lot of solar panels going up in the far North of the United States; that doesn't mean we won't do it in Arizona. This is not a competition. We're all going to win in this together. That's what a partnership in innovation means."

Dr. Ebinger said he wanted to "add some reality" to the discussion. First, he said, German is part of the EU, which has broad energy goals. The International Energy Agency projects that the world is still going to derive about 85 percent of its energy from fossil fuels in 2050, even if Germany meets its targets for renewables. He said that Germany, as a great technological nation, could make valuable contributions to the science of CCS from coal and natural gas, the dominant fuels. "If we don't solve those problems," he said, "it doesn't matter what else we do about climate change, we'll all burn together."

Germany as a Model and Exemplar

Mrs. Kotting-Uhl replied that Germany's best contribution to the global effort to lower carbon emission is as a model and exemplar. "I think that there has to be a country, among the highly-industrialized, which shows, first, economic standards and exports and success; secondly, a high quality of life; third, climate protection; and, fourth, a nuclear phase-out. Germany is on track to model all these features. If we ask ourselves, where should the world be in 2050, we should care not so much about countries like Germany, France, and the Scandinavian countries, which are all relatively small, but the developing and emerging nations, which are still developing their energy systems, standard of living, and economic power. If they reach for coal and nuclear, the risk is too high. If a high-tech country like Japan is not in a position to protect their nuclear power from the forces of nature, then I don't think that any nation can disregard this. The only way to guarantee safety—and a long, extremely cheap, economical energy supply that can also create many jobs—is renewable energy combined with efficiency technology. Some country must follow this path, and I will be happy if this is Germany."

Mr. Rossman said he wanted to make three additional points. First, he recalled as a young socialist protesting against nuclear power and reading a book

by an adviser of U.S. President Jimmy Carter favoring energy conservation, especially in nations that thought energy was always in surplus. "I was very impressed," he said, "because I thought that there was, finally, in this big, admirable country, a world perspective that included responsibility for all." Later, he said, Al Gore also thought in terms of common responsibility.

Second, he said that Germany was very much in the tradition of the Carter doctrine and the practice of Al Gore, a path toward renewable energy and energy efficiencies. That is a true international perspective, he said, enabling all countries to share the most modern technological options to develop what they need.

The alternative is to advise them to take the path of large coal and nuclear plants. "This cannot be a development perspective," he said, "and is why, from the German and European viewpoint, renewable energy should be the priority. We should serve as a model for these countries that renewables represent a secure, tradable energy supply, providing for mobility, health, and education in every country."

100 Percent Renewables: 'For Now, It is Just an Idea'

Third, he recalled being severely shaken by the nuclear accident at Three Mile Island, near Harrisburg, Pennsylvania in 1979. And since the disaster in Japan, he said, he thinks often about California, and the likelihood of a large earthquake catastrophe there. "Wind energy, photovoltaics, and biogas just don't pose these catastrophic questions of nuclear meltdowns and radioactive clouds. So I see myself there, aligned with America's earliest ideas for reform."

Mr. Rupprecht said that nuclear energy is evaluated in Germany differently than it is in neighboring countries. He said his constituency lives near the border of the Czech Republic and its nuclear plants, and if Germany switches off its power plants, his people will still live closer to the Czech plants than to the plants in Bavaria. "On what grounds can I can argue for this phase-out in terms of safety?" he asked. Given the many uncertainties, he said it would be 10 or 15 years before the German model could be judged a success.

"Right now," he said, "we argue self-consciously and offensively. Nothing guarantees that this route will be successful." While the phase-out has been delayed to 2020 or beyond, he worried about "whether the burden will fall on the population: the construction of pipeline networks, support of wind turbines, etc. It will take about fifteen years until we can see whether Germany's path is really attractive and whether it can be a model for other countries. For now, it is just an idea."

Closing Remarks

Alan Wm. Wolff
Dewey & LeBoeuf LLP
and
Chair, U.S. National Academies Committee
on Comparative National Innovation Policies

Mr. Wolff commented that the spirited exchanges of the roundtable signified both the uncertainties and the urgency of innovation policy, especially in regard to energy issues. He returned to a primary theme of the workshop, cooperation and competition between the two countries, and underlined the need for both if the technological and policy challenges are to be clarified and addressed. "I think today that Germany and the United States demonstrated how much we have to offer each other." He closed by thanking his hosts in Berlin, and urging that the dialogue continue to support what turned out to be a "major undertaking."

Klaus F. Zimmermann
Director, Institute for the Study of Labor (IZA)
and
German Institute for Economic Research (DIW Berlin)

Dr. Zimmerman closed the symposium with words of thanks and gratitude for the participants and organizers, and for the many informative talks packed into two days.

Looking beyond the symposium, he urged his colleagues not only to continue monitoring the issues raised during discussions, but also to give great attention to issues not much discussed, especially that of security, and how best to deal with catastrophes. He also emphasized importance of the service sector, on which much employment depends, and the employment consequences of innovation.

He concluded by urging both partner countries to maintain the "freshness of debate between and with the policy makers directly," and to share and shape transatlantic responses to policy challenges. "What can the United States and Germany do together," he asked, "to make the best contribution?"

III

APPENDIXES

Appendix A

Agenda
Meeting Global Challenges: German-U.S. Innovation Policy

Organized jointly by the German Institute for Economic Research and the U.S. National Academies

May 24-25, 2011

Berlin

Day 1—May 24, 2011

9:15 AM	**Welcome** *Gert G. Wagner, Chairman, Executive Board, German Institute for Economic Research (DIW Berlin)* *Alan Wm. Wolff, Dewey & LeBoeuf LLP and Chair, U.S. National Academies Committee on Comparative National Innovation Policies*
9:45 AM	**Opening Remarks for Germany** *Georg Schütte, State Secretary for Education and Research*
10:00 AM	**Opening Remarks for the United States** *The Honorable Philip Murphy, U.S. Ambassador to Germany*
10:15 AM	**Keynote Address** *John Fernandez, Assistant Secretary, U.S. Economic Development Administration*
10:45 AM	**Coffee Break**

11:00 AM **Panel I: Current Trends in Innovation Policy**
Moderator: Jens Schmidt-Ehmcke, German Institute for Economic Research (DIW Berlin)

U.S. Innovation Policy: New Initiatives
Ginger Lew, Senior Counselor, White House National Economic Council

New Initiatives in German Innovation Policy
Dietmar Harhoff, Chairman, Commission of Experts for Research and Innovation

Policy Initiatives at the U.S. National Institute of Standards and Technology
Phillip Singerman, Associate Director for Innovation and Industry Services, U.S. National Institute of Standards and Technology (NIST)

Discussion

12:00 PM **Lunch**

12:45 PM **Keynote Address**
Werner Hoyer, Minister of State at the Foreign Office (Auswertiges Amt)

1:15 PM **Panel II: Competition and Cooperation in a Global Economy**
Moderator: Katharina Schlüter, Finance-Magazin

Chinese and Indian Investments and Economic Strategy
Carl Dahlman, Henry R. Luce Associate Professor, Georgetown University School of Foreign Service, and Member, U.S. National Academies Committee on Comparative National Innovation Policies

Innovation and Trade
Alan Wm. Wolff, Dewey & LeBoeuf LLP and Chair, U.S. National Academies Committee on Comparative National Innovation Policies

Discussion

2:15 PM **Panel III: Human Resources, Competition for Manpower, and the Internationalization of Labor**
Moderator: Irwin Collier, John F. Kennedy Institute, Free University Berlin (FU Berlin)

The Human Resource Challenge
Klaus F. Zimmermann, Director, Institute for the Study of Labor (IZA), and German Institute for Economic Research (DIW Berlin)

A Microsoft Perspective on the United States and Europe
Jan Muehlfeit, Chairman Europe, Microsoft Corporation

Discussion

3:00 PM **Coffee Break**

3:15 PM **Panel IV: Growing Universities for the 21st Century**
Moderator: Reinhard Grunwald, Director, Zentrum für Wissenschaftsmanagement e.V. Speyer (ZWM)

Challenges and Changes for German Research Institutions
Karl Ulrich Mayer, President, Leibniz Association

Growing the New Akron University
Luis Proenza, President, The University of Akron

German Universities and the Role of the Excellence Initiative
Andreas Pinkwart, Dean, Leipzig Graduate School of Management, (Handelshochschule Leipzig)

Discussion

4:15 PM **Roundtable—**
"Competition and Cooperation: Systematic Challenges"
Chair: Peter Engardio, Senior Writer, BusinessWeek (retired)

Alan Wm. Wolff, Dewey & LeBoeuf LLP and Chair, U.S. National Academies Committee on Comparative National Innovation Policies

Engelbert Beyer, Head of Directorate for Innovation Strategies, Federal Ministry of Education and Research

Carl Dahlman, Henry R. Luce Associate Professor, Georgetown University School of Foreign Service, and Member, U.S. National Academies Committee on Comparative National Innovation Policies

Thomas A. Curran, Senior Vice President for Technology and Innovation, Deutsche Telekom AG

5:00 PM **Adjourn Day 1**

Day 2—May 25, 2011

9:00 AM **Welcome and Opening Remarks**
Klaus F. Zimmermann, Director, Institute for the Study of Labor (IZA), and German Institute for Economic Research (DIW Berlin)

9:15 AM **Panel V: Helping Small Business: Current Trends and Programs**
Moderator: David Audretsch, Director, Institute for Development Strategies, Indiana University

The "Mittelstand" Programs and Innovation in Germany
Rainer Jäkel, Head, Directorate for Technology and Innovation Policies, Federal Ministry of Economics and Technology (BMWi)

Small Business Innovation: Federal Investments to Cross the Valley of Death
Charles W. Wessner, Director, Technology, Innovation, and Entrepreneurship, The U.S. National Academies

Discussion

10:15 AM **Coffee Break**

10:30 PM **Panel VI: Early-Stage Finance and Entrepreneurship**
Moderator: Alexander Kritikos, Research Director, German Institute for Economic Research (DIW Berlin)

New Initiatives in Early-Stage Finance in Germany
Peter Terhart, Chairman, German Private Equity and Venture Capital Association (BVK)

The Clash of Innovation Cultures:
The United States and Germany
Eran Davidson, Managing Partner, Hasso Plattner Ventures

Trends and Challenges for Venture Capital
in the United States
Arati Prabhakar, Partner, U.S. Venture Partners

Discussion

11:30 PM **Panel VII: Policies and Programs for CO_2 Reduction**
Moderator: Claudia Kemfert, Head of Energy, Transportation, and Environment Department, German Institute for Economic Research (DIW Berlin)

The "Morgenstadt" Concept
Frauke Lohr, Senior Partner, Grolman.Result GmbH

U.S. Carbon Reduction Policies
Charles Ebinger, Director, Energy Security Initiative, The Brookings Institution

Climate Change and Innovation:
Mitigation and Adaptation Measures
Reinhard F. Hüttl, Scientific Executive Director, Helmholtz Centre Potsdam/GFZ, and President, acatech, the German Academy of Science and Engineering

Discussion

12:45 PM **Lunch**

1:45 PM **Panel VIII: Building Electric Vehicle Industries**
Moderator: Andreas Möller, Head of Division Policy and Social Consulting, acatech, the German Academy of Science and Engineering

U.S. Battery Initiative for Electric Drive Vehicles
Ed Owens, Supervisory General Engineer for Vehicle Technologies, U.S. Department of Energy

German Developments in Electric Vehicles
Dirk Arnold, Deputy Head of Division, Environmental Innovation and Electric Mobility, Federal Ministry of Economics and Technology (BMWi)

2:20 PM **Discussion**

2:30 PM **Panel IX: Medical/Biomedical Innovation for the 21st Century**
Moderator: Charles W. Wessner, Director, Technology, Innovation, and Entrepreneurship, The U.S. National Academies

Advancing Innovation and Convergence in Cancer Research
Jerry S. H. Lee, Deputy Director, Center for Strategic Scientific Initiatives, U.S. National Cancer Institute

Medical/Biomedical Innovation for the 21st Century
Joachim Giesekus, Strategic Marketing, Fraunhofer Heinrich Hertz Institute (HHI)

Discussion

3:30 PM **Coffee Break**

4:00 PM **Panel X: Policies and Programs to Build Solar Industries**
Moderator: Peter Strunk, WISTA Management GmbH and Adlershof Science Park, Berlin

The German Solar Industry
Karsten Neuhoff, Director, Climate Policy Initiative (CPI-Berlin)

U.S. Initiatives in Solar Energy Policy
Minh Le, Chief Engineer, Solar Energy Technologies Program, U.S. Department of Energy

Discussion

4:45 PM **Roundtable—**
"Energy Change: What are the Consequences for the German and U.S. Innovation Systems?"
Chair: Tim Stuchtey, Director, Brandenburgisches Institut für Gessellschaft und Sicherheit

Seth Winnick, Counselor for Economic Affairs, Embassy of the United States

Sylvia Kotting-Uhl, Green Party; Member, Committee for Education, Research, and Technology Assessment

Albert Rupprecht (CSU) Committee for Education, Research, and Technology

Ernst Dieter Rossman, Social Democratic Party, Shlezvik Holstein (SPD); Member, Committee for Research, Education, and Technology

Arati Prabhakar, Partner, U.S. Venture Partners

5:45 PM **Closing Remarks**
Alan Wm. Wolff, Dewey & LeBoeuf LLP and Chair, U.S. National Academies Committee on Comparative National Innovation Policies

Klaus F. Zimmermann, Director, Institute for the Study of Labor (IZA), and German Institute for Economic Research (DIW Berlin)

6:15 PM **Adjourn**

Appendix B

Bibliography

Acs, Zoltan, and David Audretsch. 1990. *Innovation and Small Firms*. Cambridge, MA: The MIT Press.

Aerts, Kris, and Dirk Czarnitzki. 2005. "Using Innovation Survey Data to Evaluate R&D Policy: The Case of Flanders." Catholic University of Leuven, Department of Applied Economics and Steunpunt O&O Statistieken.

Aerts, Kris, and Dirk Czarnitski. 2006. "The Impact of Public R&D Funding in Flanders." *IWT Studies* 54.

Aghion, Phillipe, Robin Burgess, Stephen Redding, and Fabrizio Zilibotti. 2003. "The Unequal Effects of Liberalization: Theory and Evidence from India." Washington, DC: Center for Economic Policy Research. Agrawal, A. and R. Henderson. 2002. "Putting Patents in Context: Exploring Knowledge Transfer from MIT." *Management Science* 48(1):44-60.

Ahluwalia, Montek Singh. 2001. "State Level Reforms Under Economic Reforms in India." Stanford University Working Paper No. 96. March.

Aizcorbe, A., S. Oliner, and D. Sichel. 2006. "Shifting Trends in Semiconductor Prices and the Pace of Technological Progress." Federal Reserve Board Finance and Economics Discussion Series Working Paper No. 2006-44. September.

Alic, John A., Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, and Gerald L. Epstein. 1992. *Beyond Spin-off: Military and Commercial Technologies in a Changing World*. Boston, MA: Harvard Business School Press.

Allen, John. 2011. "House continuing resolution would bar NASA from China ties." *Politico* February 12.

Allen, Stuart D., Albert N. Link, and Dan T. Rosenbaum. 2007. "Entrepreneurship and Human Capital: Evidence of Patenting Activity from the Academic Sector." *Entrepreneurship Theory and Practice* 31(6):937-951.

Allison, J., and M. Lemley. 1998. "Empirical Evidence on the Validity of Litigated Patents." *AIPLA Quarterly Journal* 26:185-277.

Altenburg, Tilman, Hubert Schmitz, and Andreas Stamm. 2008. "Breakthrough: China's and India's Transition from Production to Innovation." *World Development* 36(2):325-344.

Amsden, Alice H. 2001. *The Rise of "the Rest": Challenges to the West from Late-industrializing Economies*. Oxford, UK: Oxford University Press.

Amsden, Alice H. and Wan-wen Chu. 2003. *Beyond Late Development: Taiwan's Upgrading Policies*. Cambridge, MA: The MIT Press.

Amsden, Alice H., Ted Tschang, and Akira Goto. 2001. "Do Foreign Companies Conduct R&D in Developing Countries?" Tokyo, Japan: ADB Institute.

Aoki, Reiko, and Sadao Nagaoka. 2004. "The Consortium Standard and Patent Pools." *The Economic Review (Keizai Kenkyu)* 55(4):345-356.

Aoki, Reiko, and Sadao Nagaoka. 2005. "Coalition Formation for a Consortium Standard through a Standard Body and a Patent Pool: Theory and Evidence from MPEG2, DVD and 3G." IIR Working Paper WP#05-01. February.

Applied Research Institute, Inc. 2006. *Survey of the Environment for Startups*. Applied Research Institute. November.

Archibugi, Danielle, Jeremy Howells, and Jonathan Michie, eds. 1999. *Innovation Policy and the Global Economy*. Cambridge, UK: Cambridge University Press.

Argyres, N. S., and J. P. Liebeskind. 1998. "Privatizing the Intellectual Commons: Universities and the Commercialization of Biotechnology." *Journal of Economic Behavior & Organization* 35:427-454.

Arora, A., and R. P. Merges. 2004. "Specialized Supply Firms, Property Rights, and Firm Boundaries." *Industrial and Corporate Change* 13(3):451-476.

Arora, A., A. Fosfuri, and A. Gambardella. 2003. "Markets for Technology and Corporate Strategy." In O. Granstrand, ed., *Economics, Law, and Intellectual Property*, Boston, MA: Kluwer Academic Publishers.

Arora, A., M. Ceccagnoli, and W. Cohen. 2001. "R&D and the Patent Premium." Carnegie-Mellon University and INSEAD: paper presented at the ASSA Annual Meetings. January 2002. Atlanta, Georgia.

Arrow, K. J. 2000. "Increasing Returns: Historiographic Issues and Path Dependence." *European Journal of the History of Economic Thought* 7(2):171-180.

Arrow, Kenneth. 1962. *The Rate and Direction of Inventive Activity*. Princeton, NJ: Princeton University Press.

Arthur, W. 1989. "Competing Technologies, Increasing Returns, and Lock-in by Historical Small Events." *Economic Journal* 99(2):116-131.

Asheim, Bjorn T., et al., eds. 2003. *Regional Innovation Policy for Small-medium Enterprises*. Cheltenham, UK: Edward Elgar.

Association of University Research Parks. 1998. "Worldwide Research & Science Park Directory 1998." New York: BPI Communications.

Association of University Research Parks. 2008 "The Power of Place: A National Strategy for Building America's Communities of Innovation." Tucson, AZ: Association of University Research Parks.

Athreye, Suma S. 2000. "Technology Policy and Innovation: The Role of Competition Between Firms." In Pedro Conceicao et al., eds. *Science, Technology, and Innovation Policy: Opportunities and Challenges for the Knowledge Economy*. Westport, CT: Quorum Books.

Atkinson, Robert. 2004. *The Past and Future of America's Economy-Long Waves of Innovation that Power Cycles of Growth*. Cheltenham, UK: Edward Elgar.

Atkinson, Robert. 2006. "Is the Next Economy Taking Shape?" *Issues in Science and Technology* Winter.

Audretsch, D. B., ed. 1998. *Industrial Policy and Competitive Advantage*. Volumes 1 and 2. Cheltenham, UK: Edward Elgar.

Audretsch, D. B. 1998. "Agglomeration and the Location of Innovative Activity." *Oxford Review of Economic Policy* 14(2):18-29.

Audretsch, D. B. 2006. *The Entrepreneurial Society*. Oxford, UK: Oxford University Press.

Audretsch, D. B., and M. P. Feldman. 1996. "R&D Spillovers and the Geography of Innovation and Production." *American Economic Review* 86(3):630-640.

Audretsch, D. B., and M. P. Feldman. 1999. "Innovation in Cities: Science-based Diversity, Specialization, and Localized Competition." *European Economic Review* 43(2):409-429.

Audretsch, D. B., B. Bozeman, K. L. Combs, M. P. Feldman, A. N. Link, D. S. Siegel, P. Stephan, G. Tassey, and C. Wessner. 2002. "The Economics of Science and Technology." *Journal of Technology Transfer* 27:155-203.

Audretsch, D. B., H. Grimm, and C. W. Wessner. 2005. *Local Heroes in the Global Village: Globalization and the New Entrepreneurship Policies*. New York: Springer.

Auerswald, Philip E., Lewis M. Branscomb, Nicholas Demos, and Brian K. Min. 2005. *Understanding Private-Sector Decision Making for Early-Stage Technology Development: A "Between Invention and Innovation Project" Report*. NIST GCR 02-841A. Gaithersburg, MD: National Institute of Standards and Technology.

Augustine, Norman. 2007. *Is America Falling Off the Flat Earth?* Washington, DC: The National Academies Press.

Baker, Stephen. 2005. "New York's Big Hopes for Nano." *BusinessWeek* February 4.

Bakouros, Y. L., D. C. Mardas, and N. C. Varsakelis. 2002. "Science Parks, a High-Tech Fantasy? An Analysis of the Science Parks of Greece." *Technovation* 22(2):123-128.

Baldwin, J. R., P. Hanl, and D. Sabourin. 2000. "Determinants of Innovative Activity in Canadian Manufacturing Firms: The Role of Intellectual Property Rights." Statistics Canada Working Paper No. 122. March.

Baldwin, John Russel, and Peter Hanel. 2003. *Innovation and Knowledge Creation in an Open Economy: Canadian Industry and International Implications*. Cambridge, UK: Cambridge University Press.

Balzat, Markus, and Andreas Pyka. 2006. "Mapping National Innovation Systems in the OECD Area." *International Journal of Technology and Globalisation* 2(1-2):158-176.

Baptista, R. 1998. "Clusters, Innovation, and Growth: A Survey of the Literature." In G. M. P. Swann, M. Prevezer, and D. Stout, eds. *The Dynamics of Industrial Clustering*. Oxford, UK: Oxford University Press.

Bartzokas, Anthony, and Morris Teubal. 2002. "The Political Economy of Innovation Policy Implementation in Developing Countries." *Economics of Innovation and New Technology* 11(4-5).

Battelle. 2009. *R&D Magazine* December.

Beinhocker, Eric D. 2007. *Origin of Wealth—Evolution, Complexity, and the Radical Remaking of Economics*. Cambridge, MA: Harvard Business School.

Bennis, Warren, and Patricia Ward Biederman. 1997. *Organizing Genius*. New York: Basic Books.

Berlin, Leslie. *The Man Behind the Microchip: Robert Noyce and the Invention of Silicon Valley*. 2005. New York: Oxford University Press.

Bessen, J., and M. J. Meurer. 2005. "The Patent Litigation Explosion." Research on Innovation and Boston University School of Law. Manuscript. August.

Bhidé, Amar. 2006. "Venturesome Consumption, Innovation and Globalization." Paper presented at the Centre on Capitalism & Society and CESifo Venice Summer Institute 2006. "Perspectives on the Performance of the Continent's Economies." July 21-22, 2006. Held at Venice International University. San Servolo, Italy.

Biegelbauer, Peter S., and Susana Borras, eds. 2003. *Innovation Policies in Europe and the U.S.: The New Agenda*. Aldershot, UK: Ashgate.

Birch, David. 1981. "Who Creates Jobs?" *The Public Interest* 65:3-14.

Blanpied, William A. 1998. "Inventing U.S. Science Policy." *Physics Today* 51(2):34-40.

Block, Fred, and Matthew Keller. 2008. "Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970-2006." The Information Technology and Innovation Forum. July.

Blomström, Magnus, Ari Kokko, and Fredrik Sjöholm. 2002. "Growth & Innovation Policies for a Knowledge Economy: Experiences from Finland, Sweden, & Singapore." EIJS Working Paper, Series No. 156.

Bloomberg News. 2012. "Germany Will Publish Progress Report on Nuclear Exit in December." July 24.

Bonvillian, William B. 2006. "Power Play, The DARPA Model and U.S. Energy Policy." *The American Interest* II(2):39-48.

Borger, Klaus, et al. 2005. *Mittelstand Monitor, 2005: Annual report on cyclical and structural issues relating to small and medium-sized enterprises,* Frankfurt am Main: KfW Bankengruppe. 2005.

Borras, Susana. 2003. *The Innovation Policy of the European Union: From Government to Governance*. Cheltenham, UK: Edward Elgar.

Borrus, Michael, and Jay Stowsky. 2000. "Technology Policy and Economic Growth." In Charles Edquist and Maureen McKelvey, eds. *Systems of Innovation: Growth, Competitiveness and Employment*. Volume 2. Cheltenham, UK: Edward Elgar.

Bradsher, Pete. 2009. "China-U.S. Trade Dispute Has Broad Implications." *New York Times* September 14.

Branscomb, L. M., and P. E. Auerswald. 2001. *Taking Technical Risks: How Innovators, Executives, and Investors Manage High-Tech Risks*. Boston, MA: The MIT Press.

Branscomb, Lewis M., and Philip E. Auerswald. 2002. *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development*. NIST GCR 02-841. Gathersburg, MD: National Institute of Standards and Technology. November.

Braudel, Fernand. 1973. *Capitalism and Material Life 1400-1800*. London, UK: Harper Colophon Books.

Breschi, S. and F. Lissoin. 2001. "Knowledge Spillovers and Local Innovation Systems: A Critical Survey." *Industrial and Corporate Change* 10(4):975-1005.

Breznitz, D. and Murphree. 2011. *Run of the Red Queen; Government, Innovation, and Globalization and Economic Growth in China.* New Haven, CT: Yale University Press.

Breznitz, Dan. 2007. *Innovation in the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland*. New Haven, CT: Yale University Press.

Broder, J. and J. Ansfield. 2009. "China and U.S. Seek a Truce on Greenhouse Gases." *The New York Times* June 7.

Browning, L., and J. Shetler. 2000. *SEMATECH: Saving the U.S. Semiconductor Industry*. College Station, TX: Texas A&M University Press.

Bush, Nathan. 2005. "Chinese Competition Policy, It Takes More than a Law." *China Business Review*. May-June.

Bush, Vannevar. 1945. *Science: The Endless Frontier*. Washington, DC: U.S. Government Printing Office.

Caliendo, Marco, and Alexander Kritikos. 2012. "Searching for the entrepreneurial personality: New evidence and avenues for further research." *Journal of Economic Psychology* 33(2):319-324.

Caliendo, Marco, Frank Fossen, and Alexander Kritikos. 2008. "The Impact of Risk Attitudes on Entrepreneurial Survival." GfA Discussion Paper No. 12/2008.

Capron, Henri, and Michele Cincera. 2006. *Strengths and Weaknesses of the Flemish Innovation System: An External Viewpoint*. Brussels, Belgium: IWT.

Caracostas, Paraskevas, and Ugur Muldur. 2001. "The Emergence of the New European Union Research and Innovation Policy." In P. Laredo and P. Mustar, eds. *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis*. Cheltenham, UK: Edward Elgar.

Cardoso, Ana Rute, Paulo Guimaraes, and Klaus Zimmermann. 2010. "Trends in Economic Research: An International Perspective." *Kyklos* 63(4):479-494.

Castells, M., and P. Hall. 1994. *Technopoles of the World*. London, UK: Oxford University Press.

Cebrowski, Arthur, and John Garska. 1998. "Network Centric Warfare: Its Origin and Future." *U.S. Naval Institute Proceedings*. January.

Center for Economic Development and Business Research. 2008. "Kansas Aviation Manufacturing," Wichita State University: W. Frank Barton School of Business. September

Chambers, John, ed. 1999. *The Oxford Companion to American Military History*. Oxford, UK: Oxford University Press.

Chan, K. F., and Theresa Lau. 2005. "Assessing Technology Incubator Programs in the Science Park: The Good, the Bad and the Ugly." *Technovation* 25(10):1215-1228.

Chand, Satish, and Kunal Sen. 2002. "Trade Liberalization and Productivity Growth: Evidence from Indian Manufacturing." *Review of Development Economics* 6(February).

Chang, Connie, Stephanie Shipp, and Andrew Wang. 2002. "The Advanced Technology Program: A Public-Private Partnership for Early-stage Technology Development." *Venture Capital* 4(4): 363-370.

Chao, Loretta. 2011. "China Plans to Ease Rules That Irked Companies." *The Wall Street Journal* July 1.

Chesbrough, Henry. 2003. *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Cambridge, MA: Harvard Business School Press. April.

China Daily. 2008. "China Luring 'Sea Turtles' Home." December 18.

China Trade Extra. 2005. China Agrees to Delay Software Procurement Rule While Talking with U.S. July 11.

Chinese Ministry of Finance. 2006. Opinions of the Ministry of Finance on Implementing Government Procurement Policies That Encourage Indigenous Innovation. Cai Ku [2006] No. 47. June 13.

Chordà, I. M. 1996. "Towards the Maturity State: An Insight into the Performance of French Technopoles." *Technovation* 16(3):143-152.

Chu Ng, Ying and Sung-ko Li, 2009. "Efficiency and productivity growth in Chinese universities during the post-reform period." *China Economic Review*. Volume 20

Chuma, Hiroyuki. 2006. "Increasing Complexity and Limits of Organization in the Microlithography Industry: Implications for Science-based Industries." *Research Policy* 35:394-411.

Chuma, Hiroyuki, and Norikazu Hashimoto. 2007. "Moore's Law, Increasing Complexity and Limits of Organization: Modern Significance of Japanese DRAM ERA." NISTEP Discussion Paper No. 44. National Institute of Science and Technology Policy.

Cimoli, Mario, and Marina della Giusta. 2000. "The Nature of Technological Change and its Main Implications on National and Local Systems of Innovation." IIASA Interim Report IR-98-029.

Cincera, Michele. 2006. *Comparison of Regional Approaches to Foster Innovation in the European Union: The Case of Flanders*. Brussels, Belgium: IWT.

Cincera, Michele. 2006. *R&D Activities of Flemish Companies in the Private Sector: An Analysis for the Period 1998-2002*. Brussels, Belgium: IWT.

Clark, B. 1995. *Places of Inquiry*. Berkeley, CA: University of California Press.

Clarke, P. 2004. "LETI, Crolles Alliance Open $350-million 32-nm Research Fab." *EE Times* April 24.

Clarke, P., M. LaPedus, and M. Santarini. 2005. "IBM-led Consortium to Build Fab in N.Y." *EE Times* January 5.

Clough, G. Wayne. 2007. "The Role of the Research University in Fostering Innovation." The Americas Competitiveness Forum. June 12.

Coakes, Elayne, and Peter Smith. 2007. "Developing Communities of Innovation by Identifying Innovation Champions." *The Learning Organization: An International Journal* 14(1):74-85.

Coburn, Christopher, and Dan Berglund. 1995. *Partnerships: A Compendium of State and Federal Cooperative Programs*. Columbus, OH: Battelle Press.

Cohen, W. 2002. "Thoughts and Questions on Science Parks." Presented at the National Science Foundation Science Parks Indicators Workshop. University of North Carolina at Greensboro.

Cohen, W., R. Florida, and R. Goe. 1992. *University-Industry Research Centers in the United States*. Pittsburgh, PA: Carnegie-Mellon University.

Cohen, W., R. Nelson, and J. Walsh. 2000. "Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not)." NBER Working Paper 7552. Cambridge, MA: National Bureau of Economic Research.

Cohen, W. M., A. Goto, A. Nagata, R. R. Nelson, and J. P. Walsh. 2002. "R&D Spillovers, Patents and the Incentives to Innovate in Japan and the United States." *Research Policy* 1425:1-19.

Cole, Jonathan R. 2010. "The Great American University: Its Rise to Preeminence, Its Indispensible National Role, Why It Must Be Protected." *Public Affairs*.

Combs, Kathryn L., and Albert N. Link. 2003. "Innovation Policy in Search of an Economic Paradigm: The Case of Research Partnerships in the United States." *Technology Analysis & Strategic Management* 15(2).

Conant, Jennet. 2002. *Tuxedo Park*. New York: Simon & Shuster.

Conant, Jennet. 2005. *109 East Palace*. New York: Simon & Shuster.

Cooper, Helene and M. Lander. 2011. "U.S. Shifts Focus to Press China for Market Access." *New York Times*. January 18

Constant, Amelie F., Bienvenue N. Tien, Klaus F. Zimmermann, and Jingzhou Meng. 2011. "China's Latent Human Capital Investment: Achieving Milestones and Competing for the Top." IZA Discussion Paper 5650.

Council on Competitiveness. 2005. *Innovate America: Thriving in a World of Challenge and Change*. Washington, DC: Council on Competitiveness.

Council on Government Relations. 2000. *Technology Transfer in U.S. Research Universities: Dispelling Common Myths*. Washington, DC: Council on Government Relations.

Crain, Mark. 2005. "The Impact of Regulatory Costs on Small Firms." SBA: SBHQ-03-M-0522. Washington, DC: Small Business Administration.

Crafts, N. F. R. 1995. "The Golden Age of Economic Growth in Western Europe, 1950-1973." *Economic History Review* 3:429-447.

Czarnitzki, Dirk, and Niall O'Byrnes. 2007. "Innovation and the Impact on Productivity in Flanders." *Tijdschrift voor Economie en Management* 52(2).

Dahlman, Carl. 2005. *India and the Knowledge Economy: Leveraging Strengths and Opportunities*. Washington, DC: World Bank Publications.

Dahlman, Carl. 2011. *The World Under Pressure: How China and India Are Influencing the Global Economy and Environment*. Palo Alto: Stanford University Press.

Dahlman, Carl, and Anuja Utz. 2005. *India and the Knowledge Economy: Leveraging Strengths and Opportunities*. Washington, DC: The World Bank.

Dahlman, Carl J., and Jean Eric Aubert. 2001. *China and the Knowledge Economy: Seizing the 21st Century*. Washington, DC: The World Bank.

Daneke, Gregory A. 1998. "Beyond Schumpeter: Non-linear Economics and the Evolution of the U.S. Innovation System." *Journal of Socio-economics* 27(1):97-117.

Darby, Michael, Lynne G. Zucker, and Andrew J. Wang. 2002. *Program Design and Firm Success in the Advanced Technology Program: Project Structure and Innovation Outcomes*. NISTIR 6943. Gaithersburg, MD: National Institute of Standards and Technology.

Das, Gurcharan. 2006. "The India Model." *Foreign Affairs* 85(4).

Dasgupta, P., and P. David. 1994. "Toward a New Economics of Science." *Research Policy* 23:487-521.

David, P. A. 1985. "Clio and the Economics of QWERTY." *American Economic Review* 75(2):332-337.

Davidsson, Per. 1996. "Methodological Concerns in the Estimation of Job Creation in Different Firm Size Classes." Working Paper, Jönköping International Business School.

Davis, Steven, John Haltiwanger, and Scott Schuh. 1993. "Small Business and Job Creation: Dissecting the Myth and Reassessing the Facts." Working Paper No. 4492. Cambridge, MA: National Bureau of Economic Research.

de Jonquieres, Guy. 2004. "China and India Cannot Fill the World's Skills Gap." *Financial Times* July 12.

de Jonquieres, Guy. 2004. "To Innovate, China Needs More than Standards." *Financial Times* July 12.
de Jonquieres, Guy. 2006. "China's Curious Marriage of Convenience." *Financial Times* July 19.
De la Mothe, J., and Gilles Paquet. 1998. "National Innovation Systems, 'Real Economies' and Instituted Processes." *Small Business Economics* 11:101-111.
De Proft, A. 2006. Presentation at National Academies symposium on "Synergies in Regional and National Policies in the Global Economy." Leuven, Belgium. September.
Debackere, Koenraad, and Reinhilde Veugelers. 2005. "The Role of Academic Technology Transfer Organizations in Improving Industry Science Links." *Research Policy* 34(3):321-342.
Debackere, Koenraad, and Wolfgang Glänzel. 2004. "Using a Bibliometric Approach to Support Research Policy Making: The Case of the Flemish BOF-key." *Scientometrics* 59(2).
Defense Advanced Research Projects Agency. 2003. *DARPA Over The Years*. Arlington, VA: Defense Advanced Research Projects Agency. October 27.
Defense Advanced Research Projects Agency. 2005. *DARPA—Bridging the Gap, Powered by Ideas*. Arlington, VA: Defense Advanced Research Projects Agency. February.
Deng, Xiaoping, General Secretary of the Communist Party of China Central Committee. 1978. Address at the First National Science Congress.
Department of Energy. 2011. *U.S.-China Clean Energy Cooperation: A Progress Report by the U.S. Department of Energy*. January.
Dirks, S and M. Keeling. 2009. Executive Report. "A Vision of Smarter Cities: How Cities Can Lead the Way into a Prosperous and Sustainable Future," IBM Global Business Services,
Doloreux, David. 2004. "Regional Innovation Systems in Canada: A Comparative Study." *Regional Studies* 38(5):479-492.
Dries, Ilse, Peer van Humbeek, and Jan Larosse. 2005. *Linking Innovation Policy and Sustainable Development in Flanders*. Paris, France: Organisation for Economic Co-operation and Development.
Eaton, Jonathan, Eva Gutierrez, and Samuel Kortum. 1998. "European Technology Policy." NBER Working Papers 6827.
Edler, J., and S. Kuhlmann. 2005. "Towards One System? The European Research Area Initiative, the Integration of Research Systems and the Changing Leeway of National Policies." *Technikfolgenabschätzung: Theorie und Praxis* 1(4):59-68.
EE Times. 2006. "Chinese Province Pays to Get 300-mm Wafer Fab." June 28.
Ehlen, Mark A. 1999. *Economic Impacts of Flow-Control Machining Technologies: Early Applications in the Automobile Industry*. NISTIR 6373. Gaithersburg, MD: National Institute of Standards and Technology.

Ehlers, Vernon J. 1998. *Unlocking Our Future: Toward a New National Science Policy, A Report to Congress by the House Committee on Science*. Washington, DC: U.S. Government Printing Office.

Ehrenberg, R. 2000. *Tuition Rising*. Cambridge, MA: Harvard University Press.

Eickelpasch, Alexander, and Michael Fritsch. 2005. "Contests for Cooperation: A New Approach in German Innovation Policy." *Research Policy* 34:1269-1282.

Electronic News. 2006. "SMIC Gets $3B Nod from Chain's Wuhan Government." May 22.

Endquist, Charles, ed. 1997. *Systems of Innovation: Technologies, Institutions, and Organizations*. London, UK: Pinter.

Energy Information Administration. 2009. "State Energy Consumption Estimates: 1960 through 2007." Tables 8-12.

Engardio, Pete. 2009. "Can the Future be Built in America? Inside the U.S. Manufacturing Crisis." *BusinessWeek* September 21.

Engel, Kristen. 2005. "Mitigating Global Climate Change in the United States: A Regional Approach." *NYU Environmental Law Journal* 14:54.

EOS Gallup Europe. 2004. "Entrepreneurship." Flash Eurobarometer 146. January.

European Commission. 2003. *Innovation in Candidate Countries: Strengthening Industrial Performance*. Luxembourg: Office for Official Publications of the European Communities, May.

European Commission. 2003. "Investing in Research: An Action Plan for Europe 2003." Luxembourg: Office for Official Publications of the European Communities.

Evans, D., and Jovanovic, B. 1989. "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints." *Journal of Political Economy* 97:808-827.

Evans, Sir Harold. 2005. *They Made America*. Sloan Foundation Project. New York: Little, Brown and Company.

Faems, Dries, Bart Van Looy, and Koenraad Debackere. 2005. "Inter-organizational Collaboration and Innovation: Toward a Portfolio Approach." *Journal of Product Innovation Management* 22(3):238-250.

Fan, W., and White, M. J. 2002. "Personal Bankruptcy and the Level of Entrepreneurial Activity." NBER Working Paper, Series 9340. Boston, MA: National Bureau of Economic Research.

Fangerberg, Jan. 2002. *Technology, Growth, and Competitiveness: Selected Essays*. Cheltenham, UK: Edward Elgar.

Federal Communications Commission. 2009. *Connecting America: The National Broadband Plan*. Washington, DC: Federal Communications Commission.

Federal Register Notice. 2004. "2004 WTO Dispute Settlement Proceeding Regarding China: Value Added Tax on Integrated Circuits." April 21.

Federal Trade Commission. 2003. *To Promote Innovation: The Proper Balance of Patent and Competition Law Policy*. Washington, DC: U.S. Government Printing Office. October.

Feigenbaum, Evan. 2003. *China's Techno-Warriors: National Security and Strategic Competition from the Nuclear to the Information Age*. Stanford: Stanford University Press.

Feldman, Maryann, and Albert N. Link. 2001. "Innovation Policy in the Knowledge-based Economy." *Economics of Science, Technology and Innovation*. Volume 23. Boston, MA: Kluwer Academic Press.

Feldman, Maryann, Irwin Feller, Janet Bercovitz, and Richard Burton. 2002. "Equity and the Technology Transfer Strategies of American Research Universities." *Management Science* 48(1):105-121.

Feller, Irwin. 1997. "Technology Transfer from Universities." In John Smart, ed. *Higher Education: Handbook of Theory and Research*. Volume XII. New York: Agathon Press.

Feller, Irwin. 2004. *A Comparative Analysis of the Processes and Organizational Strategies Engaged in by Research Universities Participating in Industry-University Research Relationships*. Final report submitted to the University of California Industry-University Cooperative Research Program. Agreement No. M-447646-19927-3.

Ferguson, R. and C. Olofsson. 2004. "Science Parks and the Development of NTBFs: Location, Survival and Growth." *Journal of Technology Transfer* 29(1):5-17.

Field, A. J. 2003. "The Most Technologically Progressive Decade of the Century." *American Economic Review* (September):1406.

Flamm, K. 1996. *Mismanaged Trade: Strategic Policy and the Semiconductor Industry*. Washington, DC: The Brookings Institution.

Flamm, K. 2003. "Microelectronics Innovation: Understanding Moore's Law and Semiconductor Price Trends." *International Journal of Technology, Policy, and Management* 3(2).

Flamm, K. 2003. "The New Economy in Historical Perspective: Evolution of Digital Technology." In *New Economy Handbook*. St. Louis, MO: Academic Press.

Foerst, Ann. 2005. *God in the Machine*. New York: Penguin Books.

Fonfria, Antonio, Carlos Diaz de la Guardia, and Isabel Alvarez. 2002. "The Role of Technology and Competitiveness Policies: A Technology Gap Approach." *Journal of Interdisciplinary Economics* 13(1-2-3):223-241.

Fong, Glenn R. 1998. "Follower at the Frontier: International Competition and Japanese Industrial Policy." *International Studies Quarterly* 42(2).

Fong, Glenn R. 2001. "ARPA Does Windows: The Defense Underpinning of the PC Revolution." *Business and Politics* 3(3).

Foray, Dominique, and Patrick Llerena. 1996. "Information Structure and Coordination in Technology Policy: A Theoretical Model and Two Case Studies." *Journal of Evolutionary Economics* 6(2).

Friedman, Thomas. 2005. *The World Is Flat: A Brief History of the 21st Century*. New York: W. H. Freeman.

Fukugawa, N. 2006. "Science Parks in Japan and Their Value-Added Contributions to New Technology-based Firms." *International Journal of Industrial Organization* 24(2):381-400.

Furman, Jeffrey L., Michael E. Porter, and Scott Stern. 2002. "The Determinants of National Innovative Capacity." *Research Policy* 31:899-933.

Gallaher, M. P., A. N. Link, and J. E. Petrusa. 2006. *Innovation in the U.S. Service Sector*. London, UK: Routledge.

Geiger, R. 1986. *To Advance Knowledge*. New York: Oxford University Press.

Geiger, R. 1993. *Research and Relevant Knowledge*. New York: Oxford University Press.

George, Gerard, and Ganesh N. Prabhu. 2003. "Developmental Financial Institutions as Technology Policy Instruments: Implications for Innovation and Entrepreneurship in Emerging Economies." *Research Policy* 32(1):89-108.

Gibb, M. J. 1985. *Science Parks and Innovation Centres: Their Economic and Social Impact*. Amsterdam, The Netherlands: Elsevier.

Goldstein, H. A., and M. I. Luger. 1990. "Science/Technology Parks and Regional Development Theory." *Economic Development Quarterly* 4(1):64-78.

Goldstein, H. A., and M. I. Luger. 1992. "University-based Research Parks as a Rural Development Strategy." *Policy Studies Journal* 20(2):249-263.

Goodwin, James C., et al. 1999. *Technology Transition*. Arlington, VA: Defense Advanced Research Projects Agency.

Government of the People's Republic of China. 2004. *Anticompetitive Practices of Multinational Companies and Countermeasures*. Administration of Industry and Commerce, Office of Antimonopoly, Fair Trade Bureau, State Administration of Industry and Commerce. May.

Government of the People's Republic of China. 2005. *Article 10: Exemptions of Monopoly Agreements*. Anti-Monopoly Law of the People's Republic of China. Revised July 27.

Government of the People's Republic of China, Ministry of Information Industry. 2006. "Outline of the 11th Five-Year Plan and Medium-and-Long-Term Plan for 2020 for Science and Technology Development in the Information Industry." Xin Bu Ke, No. 309, August 29.

Government of the People's Republic of China, National Development and Reform Commission. 2006. *The 11th Five-Year Plan*. March 19.

Grande, Edgar. 2001. "The Erosion of State Capacity and European Innovation Policy: A Comparison of German and EU Information Technology Policies." *Research Policy* 30(6):905-921.

Grayson, L. 1993. *Science Parks: An Experiment in High-Technology Transfer*. London, UK: The British Library Board.

Griffing, Bruce. 2001. "Between Invention and Innovation, Mapping the Funding for Early-Stage Technologies." Presentation at Carnegie Conference Center. Washington, DC. January 25.

Griliches, Z. 1993. "The Search for R&D Spillovers." *Scandinavian Journal of Economics* 94(S): S29-S47.

Grindley, Peter, David Mowery, and Brian Silverman. 1994. "SEMATECH and Collaborative Research: Lessons in the Design of High Technology Consortia." *Journal of Policy Analysis and Management* 13(4):723-758.

Grove, A. 2001. *Swimming Across*. New York: Warner Books.

Gu, Shulin and Lundvall Bengt-Åke. 2006. "Policy learning as a key process in the transformation of the Chinese Innovation Systems." In *Asian Innovation Systems in Transition*. Edward Elgar Publishing Ltd.

Guy, I. 1996. "A Look at Aston Science Park." *Technovation* 16(5):217-218.

Guy, I. 1996. "New Ventures on an Ancient Campus." *Technovation* 16(6):269-270.

Hackett, S. M., and D. M. Dilts. 2004. "A Systematic Review of Business Incubation Research." *Journal of Technology Transfer* 29(1):55-82.

Hall, B. H. 2002. "The Assessment: Technology Policy." *Oxford Review of Economic Policy* 18(1):1-9.

Hall, B. H. 2005. "Exploring the Patent Explosion." *Journal of Technology Transfer* 30:35-48.

Hall, B. H., A. N. Link, and J. T. Scott. 2001. "Barriers Inhibiting Industry from Partnering with Uni-versities: Evidence from the Advanced Technology Program." *Journal of Technology Transfer* 26(1-2):87-98.

Hall, B. H., A. N. Link, and J. T. Scott. 2003. "Universities as Research Partners." *Review of Economics and Statistics* 85(2):485-491.

Hall, B. H., A. Jaffe, and M. Trajtenberg. 2005. "Market Value and Patent Citations." *RAND Journal of Economics* 36:16-38.

Hall, B. H., and R. H. Ziedonis. 2001. "The Patent Paradox Revisited: An Empirical Study of Patenting in the U.S. Semiconductor Industry. 1979-1995." *RAND Journal of Economics* 32:101-128.

Halpern, Mark. 2006. "The Trouble with the Turing Test." *The New Atlantis* 11(Winter):42-63.

Hane, G. 1999. "Comparing University-Industry Linkages in the United States and Japan." In L. Branscomb, F. Kodama, and R. Florida, eds. *Industrializing Knowledge*. Cambridge, MA: The MIT Press.

Hansson, F., K. Husted, and J. Vestergaard. 2005. "Second Generation Science Parks: From Structural Holes Jockeys to Social Capital Catalysts of the Knowledge Society." *Technovation* 25(9):1039-1049.

Hart, David. 1998. *Forged Consensus*. Princeton, NJ: Princeton University Press.

Hashimoto, T. 1999. "The Hesitant Relationship Reconsidered: University-Industry Cooperation in Postwar Japan." In Lewis M. Branscomb, Fumio Kodama, and Richard Florida, eds. *Industrializing Knowledge: University-Industry Linkage in Japan and the United States*. Cambridge, MA: The MIT Press.

Hassan, Mohamed H.A. 2005. "Small Things and Big Changes in the Developing World." *Science* 309: 65-66. July 1.

Hayashi, Fumio, and Edward C. Prescott. 2002. "The 1990s in Japan: A Lost Decade." *Review of Economic Dynamics* 5(1):206-235.

Heller, M., and R. Eisenberg. 1998. "Can Patents Deter Innovation? The Anticommons in Biomedical Research." *Science* 280:698.

Henderson, J. V. 1986. "The Efficiency of Resource Usage and City Size." *Journal of Urban Economics* 19(1):47-70.

Henderson, Jennifer A., and John J. Smith. 2002. "Academia, Industry, and the Bayh-Dole Act: An Implied Duty to Commercialize." White Paper. Center for the Integration of Medicine and Innovative Technology. Harvard University. October.

Henderson, R., L. Orsenigo, and G. P. Pisano. 1999. "The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions among Scientific, Institutional, and Organizational Change." In D. C. Mowery and R. R. Nelson, eds. *Sources of Industrial Leadership*. Cambridge, UK: Cambridge University Press.

Henderson, R., M. Trajtenberg, and A. Jaffe. 1998. "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988." *Review of Economics and Statistics* 80(1):119-127.

Hicks, D., T. Breitzman, D. Olivastro, and K. Hamilton. 2001. "The Changing Composition of Innovative Activity in the U.S.—A Portrait Based on Patent Analysis." *Research Policy* 30(4):681-704.

Hilpert, U., and B. Ruffieux. 1991. "Innovation, Politics and Regional Development: Technology Parks and Regional Participation in High-Technology in France and West Germany." In U. Hilpert, ed. *Regional Innovation and Decentralization: High-Technology Industry and Government Policy*. London, UK: Routledge.

Himmelberg, C., and B. C. Petersen. 1994. "R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries." *Review of Economics and Statistics* 76(1):38-51.

Holtz-Eakin, D., D. Joulfian, and H. Rosen. 1994. "Striking it Out: Entrepreneurial Survival and Liquidity Constraints." *Journal of Political Economy* 102(1):53-75.

Hoshi, Takeo, and Anil Kashyap. 2004. "Japan's Economic and Financial Crisis: An Overview." *The Journal of Economic Perspectives* Winter.

Howell, Thomas, et al. 2003. *China's Emerging Semiconductor Industry*. San Jose, CA: Semiconductor Industry Association, October.

Hu, Jintao. General Secretary of the Communist Party of China Central Committee. 2005. Keynote Speech. November 27.

Hu, Jintao. General Secretary of the Communist Party of China Central Committee. 2007. Speech to the Seventeenth Communist Party of China National Conference. October.

Hu, Jintao. President of China. 2009. Speech to United Nations General Assembly. September 22.

Hu, Zhijian. 2006. "IPR Policies In China: Challenges and Directions." Presentation at Industrial Innovation in China. Levin Institute Conference. July 24-26.

Huang, Can, C. Amorim, M. Spinoglio, B. Gouveia and A. Medina. 2004. "Organization, Programme and Structure:An Analysis of the Chinese Innovation Policy Framework." *R&D Management* 34(4).

Huang, Yasheng, and Tarun Khanna. 2003."Can India Overtake China?" *Foreign Policy* July-August.

Huddleson, Lillian, and Vicki Daitch. 2002. *True Genius—The Life and Science of John Bardeen*. Washington, DC: Joseph Henry Press.

Hughes, Kent. 2005. *Building the Next American Century: The Past and Future of American Economic Competitiveness*. Washington, DC: Woodrow Wilson Center Press. Chapter 14.

Hughes, Kent. 2005. "Facing the Global Competitiveness Challenge." *Issues in Science and Technology* XXI(4):72-78.

Hulsink, W., H. Bouwman, and T. Elfring. 2007. "Silicon Valley in the Polder? Entrepreneurial Ðynamics, Virtuous Clusters and Vicious Firms in the Netherlands and Flanders." *ERIM Report Series Research in Management* (ERS-2007-048-ORG).

Hundley, Richard O. 1999. *Past Revolutions, Future Transformations: What Can the History of Revolutions in Military Affairs Tell Us About Transforming the U.S. Military*. Rand Corporation National Research Institute.

Iansati, Marco, and Roy Levien. 2005. *The Keystone Advantage*. Cambridge, MA: Harvard Business School Press.

Industrial Research Institute, Inc. 2001. "Industry-University Intellectual Property." Position Paper. External Research Directors Network. April.

Inkpen, Andrew C. and Wang Pien. 2006. "An Examination of Collaboration and Knowledge Transfer: China-Singapore Suzhou Industrial Park." *Journal of Management Studies* 43(4):779-811.

Inside U.S.-China Trade. 2006. "Industry Worried China Backing out of Commitment to Join GPA." September 27.

Jacob, Klaus, et al. 2005. "Lead Markets for Environmental Innovations." *ZEW Economic Studies*. Volume 27. Heidelberg: Physica-Verlag.

Jacobs, Tom. 2002. "Biotech Follows Dot.com Boom and Bust." *Nature* 20(10):973.

Jaffe, A. B. 1989. "Real Effects of Academic Research." *American Economic Review* 79(5):957-970.

Jaffe, A. B. 1997. *Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program*. NIST GCR 97-708. Gaithersburg, MD: National Institute of Standards and Technology.

Jaffe, A. B. 1998. "The Importance of 'Spillovers' in the Policy Mission of the ATP." *Journal of Technology Transfer* 23(1):11-19.

Jaffe, A. B. 2000. "The U.S. Patent System in Transition: Policy Innovation and the Innovation Process." *Research Policy* 29:531-557.

Jaffe, A. B., and J. Lerner. 2006. *Innovation and Its Discontents: How Our Broken Patent System Is Endangering Innovation and Progress, and What to Do About It*. Princeton, NJ: Princeton University Press.

Jaffe, A. B., J. Lerner, and S. Stern, eds. 2003. *Innovation Policy and the Economy*. Volume 3. Cambridge, MA: The MIT Press.

Jaffe, A. B., M. Trajtenberg, and R. Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* 108(3):577-598.

Jasanoff, Sheila, ed. 1997. Comparative Science and Technology Policy. Elgar Reference Collection. *International Library of Comparative Pubic Policy*. Volume 5. Cheltenham, UK: Edward Elgar.

Jorgenson, D. W. 2001. "Information Technology and the U.S. Economy." *American Economic Review* 91(1) March.

Jorgenson, D. W. 2001. "U.S. Economic Growth in the Information Age." *Issues in Science and Technology* Fall.

Jorgenson, D. W., and K. Motohashi. 2003. "The Role of Information Technology in the Economy: Comparison between Japan and the United States." Prepared for RIETI/KEIO Conference on Japanese Economy: Leading East Asia in the 21st Century? Keio University. May 30.

Jorgenson, D. W. et al. 2005. *Productivity: Information Technology and the American Growth Resurgence*. Cambridge MA: MIT Press. 2005.

Joy, William. 2000. "Why the Future Does Not Need Us." *Wired* 8.04. April.

Kaelble, Steve. 2004. "Good Neighbors: Indiana's Certified-Technology-park Program." *Indiana Business Magazine* July 1.

Kaiser, Ulrich, et al. 2011. "Labor Mobility, Social Network Effects, and Innovative Activity." IZA Discussion Paper No. 5654.

Kapur, Devesh. 2003. "Indian Diaspora as a Strategic Asset." *Economic and Political Weekly* 38(5):445-448.

Kawamoto, Takuji. 2004. "What Do the Purified Solow Residuals Tell Us about Japan's Lost Decade?" Bank of Japan IMES Discussion Paper Series. No. 2004-E-5. Tokyo, Japan: Bank of Japan.

Kenney, Martin, ed. 2000. *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford, CA: Stanford University Press.

Ketzler, Rolf, and Klaus F. Zimmermann. 2009. "Publications: German Economic Research Institutes on Track." *Scientometrics* 80(1):233-254.

Kim, Linsu. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Boston: Harvard Business School Press.

Kim, Yong-June. 2006. "A Korean Perspective on China's Innovation System." Presentation at Industrial Innovation in China. Levin Institute Conference. July 24-26.

Kinast, Juliane, Christian Reiermann, and Michael Sauga. 2007. "Labor Paradox in Germany: Where have the Skilled Workers Gone?" *Spiegel Online* June 22.

Kneller, R. 2003. "University-Industry Cooperation and Technology Transfer in Japan Compared with the U.S.: Another Reason for Japan's Economic Malaise?" *Journal of International Economic Law* 24:329-450.

Koizumi, Kei. 2007. "Historical Trends in Federal R&D." In *AAAS Report XXXII: Research and Development FY2008*. AAAS Publication Number 07-1A. Washington, DC: American Association for the Advancement of Science.

Kondo, Masayuki. 2003. "Chinese Model to Create High-Tech Start-Ups from Universities and Research Institutes." In M. von Zedtwitz, G. Haour, T. Khalil, and L. Lefebvre, eds. *Management of Technology: Growth through Business, Innovation and Entrepreneurship*. Oxford, UK: Pergamon Press.

Kondo, Masayuki. 2004. "Policy Innovation in Science and Technology in Japan—from S&T Policy to Innovation Policy." (In Japanese.) *Journal of Science Policy and Research Management* 19(3/4):132-140.

Kondo, Masayuki. 2005. "Spin-offs from Public Research Institutes as Domestic Technology Transfer Means—The Case of RIKEN and Riken Industrial Group." (In Japanese.) *Development Engineering* 11:31-41.

Kortum, S., and J. Lerner. 1999. "What is Behind the Recent Surge in Patenting?" *Research Policy* 28:1-22.

Koschatzky, Knut. 2003. "The Regionalization of Innovation Policy: New Options for Regional Change?" In G. Fuchs and Phil Shapira, eds. *Rethinking Regional Innovation: Path Dependency or Regional Breakthrough?* London, UK: Kluwer.

Krugman, Paul. 1991. *Geography and Trade*. Cambridge, MA: MIT Press.

Krugman, Paul. 1994. "Competitiveness: A Dangerous Obsession." *Foreign Affairs* March/April.

Kuhlmann, Stephan and Jakob Edler. 2003. "Scenarios of Technology and Innovation Policies in Europe: Investigating Future Governance—Group of 3." *Technological Forecasting & Social Change* 70.

Kumar, Deepak. 1995. *Science and the Raj: 1857-1905*. New York: Oxford University Press.

Lall, Sanjaya. 2002. "Linking FDI and Technology Development for Capacity Building and Strategic Competitiveness." *Transnational Corporations* 11(3):39-88.

Lanjouw, J. O., and I. Cockburn. 2000. "Do Patents Matter? Empirical Evidence after GATT." NBER Working Paper No. 7495.

Lanjouw, J. O., and J. Lerner 1997. "The Enforcement of Intellectual Property Rights: A Survey of the Empirical Literature." NBER Working Paper No. W6296. Boston: National Bureau of Economic Research.

Laredo, Philippe, and Philippe Mustar, eds. 2001. *Research and Innovation Policies in the New Global Economy: An International Perspective*. Cheltenham, UK: Edward Elgar.

Larosse, J. 2004. *Towards a 'Third Generation' Innovation Policy in Flanders: Policy Profile of the Flemish Innovation*. Brussels, Belgium: IWT.

Lazowska, Edward D., and David Paterson. 2005. "An Endless Frontier Postponed." *Science* 308(5723):757. May 6.

Lebra, Takie Sugiyama. 1971. "The Social Mechanism of Guilt and Shame: The Japanese Case." *Anthropological Quarterly* 44(4):241-255.

Lembke, Johan. 2002. *Competition for Technological Leadership: EU Policy for High Technology*. Cheltenham, UK: Edward Elgar.

Lemola, Tarmo. 2002. "Convergence of National Science and Technology Policies: The Case of Finland." *Research Policy* 31(8-9):1481-1490.

Lerner, J. 1995. "Patenting in the Shadow of Competitors." *Journal of Law and Economics* 38(October):463-495.

Lerner, J. 2002. "Patent Policy Shifts and Innovation Over 150 Years." *American Economic Review P&P*. May.

Lerner, J., and J. Tirole. 2004. "Efficiency of Patent Pools." *American Economic Review* 94(3):691-711.

Leslie, Stuart, and Robert Kargon. 2006. "Exporting MIT." *Osiris* 21:110-130.

Levin, R. C., A. K. Klevorick, R. R. Nelson, and S. G. Winter. 1987. "Appropriating the Returns to Industrial R&D." *Brookings Papers on Economic Activity* 783-820.

Levitt, Rachelle, ed. 1987. *The University/Real Estate Connection: Research Parks and Other Ventures*. Washington, DC: Urban Land Institute.

Lewis, James A. 2005. *Waiting for Sputnik: Basic Research and Strategic Competition*. Washington, DC: Center for Strategic and International Studies.

Leyden, D. P., A. N. Link, and D. S. Siegel. 2008. "A Theoretical and Empirical Analysis of the Decision to Locate on a University Research Park." *IEEE Transactions on Engineering Management* 55(1):23-28.

Li, Jianjun. 2006. "The Development and Opening of Tianjin Binhai: New Area & China's Biotechnical Innovations." Presentation at Industrial Innovation in China. Levin Institute Conference. July 24-26.

Licklider, J. C. R. 1960. "Man-Computer Symbiosis." *IRE Transactions on Human Factors in Electronics*. March.

Lin, Otto. 1998. "Science and Technology Policy and its Influence on the Economic Development of Taiwan." In Henry S. Rowen, ed. *Behind East Asian Growth: The Political and Social Foundations of Prosperity*. New York: Routledge.

Lindelöf, P., and H. Löfsten. 2003. "Science Park Location and New Technology-Based Firms in Sweden: Implications for Strategy and Performance." *Small Business Economics* 20(3):245-258.

Lindelöf, P. and H. Löfsten. 2004. "Proximity as a Resource Base for Competitive Advantage: University-Industry Links for Technology Transfer." *Journal of Technology Transfer* 29(3-4): 311-326.
Lindh, T., and Ohlsson, H. 1996. "Self-Employment and Windfall Gains: Evidence from the Swedish Lottery." *Economic Journal* 106:1515-1526.
Link, A. N. 1981. "Basic Research and Productivity Increase in Manufacturing: Some Additional Evidence." *American Economic Review* 71(5):1111-1112.
Link, A. N. 1981. *Research and Development Activity in U.S. Manufacturing*. New York: Praeger.
Link, A. N. 1995. *A Generosity of Spirit: The Early History of the Research Triangle Park.* Research Triangle Park, NC: University of North Carolina Press for the Research Triangle Park Foundation.
Link, A. N. 2002. *From Seed to Harvest: The Growth of the Research Triangle Park*. Research Triangle Park, NC: University of North Carolina Press for the Research Triangle Park Foundation.
Link, A. N., and D. S. Siegel. 2003. *Technological Change and Economic Performance*. London, UK: Routledge.
Link, A. N., and J. T. Scott. 1998. *Public Accountability: Evaluating Technology-Based Institutions*. Norwell, MA: Kluwer Academic Publishers.
Link, A. N., and J. T. Scott. 2001. "Public/Private Partnerships: Stimulating Competition in a Dynamic Market." *International Journal of Industrial Organization* 19(5):763-794.
Link, A. N., and J. T. Scott. 2003. "The Growth of Research Triangle Park." *Small Business Economics* 20(2):167-175.
Link, A. N., and J. T. Scott. 2003. "U.S. Science Parks: The Diffusion of an Innovation and Its Effects on the Academic Mission of Universities." *International Journal of Industrial Organization* 21(9):1323-1356.
Link, A. N., and J. T. Scott. 2005. "Opening the Ivory Tower's Door: An Analysis of the Determinants of the Formation of U.S. University Spin-Off Companies." *Research Policy* 34(7):1106-1112.
Link, A. N., and J. T. Scott. 2006. "U.S. University Research Parks." *Journal of Productivity Analysis* 25(1):43-55.
Link, A. N., and J. T. Scott. 2007. "The Economics of University Research Parks." *Oxford Review of Economic Policy* 23(4):661-674.
Link, A. N., and K. R. Link. 2003. "On the Growth of U.S. Science Parks." *Journal of Technology Transfer* 28(1):81-85.
Litan, Robert E., and Lesa Mitchell. 2008. "Should Universities be Agents of Economic Development?" *Astra Briefs* 7(7-8).
Locke, Gary. 2010. "Remarks on Clean Energy Trade Mission to China, Indonesia." Briefing at the Washington Foreign Press Center. May 12.
Löfsten, Hans, and Peter Lindelöf. 2002. "Science Parks and the Growth of New Technology-based Firms—Academic-industry Links, Innovation and Markets." *Research Policy* 31(6):859-876.

Long, Guogiang. 2005. "China's Policies on FDI: Review and Evaluation." In Theodore H. Moran, Edward M. Graham, and Magnus Blomström, eds. *Does Foreign Direct Investment Promote Development?* Washington, DC: Institute for International Economics.

Luger, M. I. 2007. "Smart Places for Smart People: Using Cluster-based Planning in the 21st Century." In *Creating Enterprise: Igniting Innovation through Business-University-Government Networks*. Cheltenham, UK: Edward Elgar.

Luger, M. I., and H. A. Goldstein. 1991. *Technology in the Garden*. Chapel Hill, NC: University of North Carolina Press.

Luger, M. I., and H. A. Goldstein. 2006. *Research Parks Redux: The Changing Landscape of the Garden*. Washington, DC: U.S. Economic Development Administration.

Lundstörm, A., and L. Stevenson. 2001. *Entrepreneurship Policy for the Future*. Stockholm, Sweden: FSF.

Lynn, Leonard. 2006. "Collaborative Advantage and China's Evolving Position in the Global Technology System." Presentation at Industrial Innovation in China. Levin Institute Conference. July 24-26.

Maddison, Angus, and Donald Johnston. 2001. *The World Economy: A Millennial Perspective*. Paris, France: Organization for Economic Co-operation and Development.

Malecki, E. J. 1991. *Technology and Economic Development*. New York: John Wiley.

Mani, Sunil. 2004. "Government, Innovation and Technology Policy: An International Comparative Analysis." *International Journal of Technology and Globalization* 1(1).

Mansfield, E. 1986. "Patents and Innovation: An Empirical Study." *Management Science* 32:173-181.

Mansfield, E. 1996. *Estimating Social and Private Returns from Innovations Based on the Advanced Technology Program: Problems and Opportunities*. GCR 99-780. Gaithersburg, MD: National Institute of Standards and Technology.

Mansfield, E. 1996. "How Fast Does New Industrial Technology Leak Out?" *Journal of Industrial Economics* 34(2):217-224.

Marshall, Andrew. 1993. "Some Thoughts on Military Revolutions-Second Version." Memorandum for the Record. August 23.

Mazuzan, George. 1988. *The National Science Foundation: A Brief History (1950-1985)*. NSF 88-16. Arlington, VA: National Science Foundation.

McKibben, William. 2003. *Enough: Staying Human in an Engineered Age*. New York: Henry Holt & Co.

Megginson, William L. 2004. "Towards a Global Model of Venture Capital?" *Journal of Applied and Corporate Finance* 16(1).

Merges, R. P. 1996. "A Comparative Look at Intellectual Property Rights and the Software Industry." In David C. Mowery, ed. *The International Software Industry*. New York: Oxford University Press.

Merges, R. P., and R. R. Nelson. 1990. "On the Complex Economics of Patent Scope." *Columbia Law Review* 90:839-916.
Merton, R. K. 1968. "The Matthew Effect in Science." *Science* 159(3810):56-63.
METI. 2003. *The 2003 White Paper on Small and Medium Enterprises in Japan*. Tokyo: Japan Small Business Research Institute.
METI. 2005. *The 2005 White Paper on Small and Medium Enterprises in Japan*. Tokyo: Japan Small Business Research Institute.
MEXT. 2004. *Annual Report on Science and Technology Promotion Measures 2004: White Paper on Science and Technology*. (Heisei 16 nendo Kagaku-Gijutu Sinkou-ni-kansuru Nenji-houkoku). MEXT.
Meyer-Krahmer, Frieder. 2001. "The German Innovation System." Pp. 205-252 in P. Larédo and P. Mustar, eds. *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis*. Cheltenham, UK: Edward Elgar.
Meyer-Krahmer, Frieder. 2001. "Industrial Innovation and Sustainability—Conflicts and Coherence." Pp. 177-195 in Daniele Archibugi and Bengt-Ake Lundvall, eds. *The Globalizing Learning Economy*. New York: Oxford University Press.
Middleton, Andrew, and Steven Bowns. With Keith Hartley and James Reid. 2006. "The Effect of Defense R&D on Military Equipment Quality." *Defense and Peace Economics* 17(2):117-139. April.
Miller, Roger, and Marcel Cote. 1987. *Growing the Next Silicon Valley: A Guide for Successful Regional Planning*. Toronto: D. C. Heath and Company.
Mills, K, E. Reynolds, and A Reamer. 2008. *Clusters and Competitiveness: A New Federal Role for Stimulating Regional Economies*. Washington, DC: Brookings Institution.
Ministry of Economy, Trade and Industry. 2006. *New Economic Growth Strategies 2006*. Tokyo, Japan: Research Institute of Economy, Trade and Industry. (In Japanese).
Mitra, Raja. 2006. "India's Potential as a Global R&D Power." In Magnus Karlsson, ed. *The Internationalization of Corporate R&D*. Östersund: Swedish Institute for Growth Policy Studies.
Miyata, Shinpei. 1983. *A Free Paradise for Scientists*. (In Japanese.) Bungeishunju.
Mody, Ashok, and Carl Dahlman. 1992. "Performance and Potential of Information Technology: An International Perspective." *World Development* 20(12):1703-1719.
Mooris, P. R. 1990. *A History of The World Semiconductor Industry*. Stevenage, UK: Peter Peregrinus Ltd.
Morrison, Wayne M. 2010. "China-U.S. Trade Issues" Washington, DC: Congressional Research Service. June 1.

Moser, P. 2001. "How Do Patent Laws Influence Innovation? Evidence from Nineteenth Century World Fairs." University of California at Berkeley. Working Paper.

Motohashi, Kazuyuki. 2005. "University-industry Collaborations in Japan: The Role of New Technology-based Firms in Transforming the National Innovation System." *Research Policy* 34:583-594.

Motohashi, Kazuyuki, and Xiao Yun. 2007. "China's Innovation System Reform and Growing Industry and Science Linkages." *Research Policy* 36:1251-1260.

Mowery, D. C., and A. A. Ziedonis. 2002. "Academic Patent Quality and Quantity Before and After the Bayh-Dole Act in the United States." *Research Policy* 31(3):399-418.

Mowery, D. C., and B. N. Sampat. 2005. "The Bayh-Dole Act of 1980 and University-Industry Technology Transfer: A Model for Other OECD Governments?" *Journal of Technology Transfer* 30(1/2):115-127.

Mowery, D. C., R. Nelson, B. Sampat, and A. Ziedonis. 2001. "The Growth of Patenting and Licensing by U.S. Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980." *Research Policy* 30.

Mowery, D. C., R. Nelson, B. Sampat, and A. Ziedonis. 2003. The Ivory Tower and Industrial Innovation. Stanford, CA: Stanford University Press.

Muro, Mark and S. Rahman. 2010. "Budget 2011: Industry Clusters as a Paradigm for Job Growth," Brookings Institution Metropolitan Policy Program. June 10.

Murphy, L. M., and P. L. Edwards. 2003. *Bridging the Valley of Death: Transitioning from Public to Private Sector Financing*. Golden, CO: National Renewable Energy Laboratory. May.

Mustar, Phillipe, and Phillipe Laredo. 2002. "Innovation and Research Policy in France (1980-2000) or the Disappearance of the Colbertist State." *Research Policy* 31:55-72.

Nadiri I. 1993. *Innovations and Technological Spillovers*. NBER Working Paper No. 4423. Boston, MA: National Bureau of Economic Research.

Nagaoka, Sadao. 2007. "Assessing the R&D Management of Firms by Patent Citation: Evidence from the U.S. Patents." *Journal of Economics & Management Strategy* 16(1).

Nagaoka, Sadao, Naotoshi Tsukada, and Tomoyuki Shimbo. 2006. "The Emergence and Structure of Essential Patents of Standards: Lessons from Three IT Standards." IIR Working Paper WP#06-08. Institute of Innovation Research. Hitotsubashi University.

Nakamura, K., Y. Okada, and A. Tohei. 2006. "Does the Public Sector Make a Significant Contribution to Biomedical Research in Japan? A Detailed Analysis of Government and University Patenting, 1991-2002." Discussion Paper Series. Competition Policy Research Center. Fair Trade Commission of Japan. CPDP25-E.

Nakayama, Yasuo, Mitsuaki Hosono, Nobuya Fukugawa, and Masayuki Kondo. 2005. *University-Industry Cooperation: Joint Research and Contract Research*. (In Japanese.) NISTEP Research Material. No. 119. Tokyo, Japan: National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology.

National Academy of Engineering. 2004. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. 2007 *Is America Falling Off the Flat Earth?* Washington, DC: The National Academies Press.

National Academy of Sciences/National Academy of Engineering/Insitute of Medicine. 2007. *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies Press.

National Institute of Science and Technology Policy and Mitsubishi Research Institute. 2005. *Government S&T Budget Analysis during the First and Second S&T Basic Plans*. (Dai-ikki oyobi dai-niki Kagaku-Gijutu-Kihonkeikaku kikanchuu no kenkyuu-kaihatu-soushi no naiyou-bunseki). NISTEP Report No. 84. March.

National Manufacturing Competitiveness Council. 2006. "The National Strategy for Manufacturing." New Delhi, India. March.

National Research Council. 1982. *Scientific Communication and National Security.* Washington, DC: National Academy Press.

National Research Council. 1987. *Balancing the National Interest: U.S. National Security Export Controls and Global Economic Competition*. Washington, DC: National Academy Press.

National Research Council. 1996. *Conflict and Cooperation in National Competition for High-technology Industry*. Washington, DC: National Academy Press.

National Research Council. 1999. *The Advanced Technology Program: Challenges and Opportunities.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 1999. *Defense Manufacturing in 2010 and Beyond*. Washington, DC: National Academy Press.

National Research Council. 1999. *Funding a Revolution: Government Support for Computing Research.* Washington, DC: National Academy Press.

National Research Council. 1999. *Industry-Laboratory Partnerships: A Review of the Sandia Science and Technology Park Initiative.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 1999. *New Vistas in Transatlantic Science and Technology Cooperation.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 1999. *The Small Business Innovation Research Program: Challenges and Opportunities.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 2000. *The Small Business Innovation Research Program: A Review of the Department of Defense Fast Track Initiative*. Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 2000. *U.S. Industry in 2000: Studies in Competitive Performance.* David C. Mowery, ed. Washington, DC: National Academy Press.

National Research Council. 2001. *The Advanced Technology Program: Assessing Outcomes.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 2001. *Building a Workforce for the Information Economy.* Washington, DC: National Academy Press.

National Research Council. 2001. *Capitalizing on New Needs and New Opportunities: Government-Industry Partnerships in Biotechnology and Information Technologies*. Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 2001. *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1998 to 2000.* Washington, DC: National Academy Press.

National Research Council. 2001. *A Review of the New Initiatives at the NASA Ames Research Center.* Charles W. Wessner, ed. Washington, DC: National Academy Press.

National Research Council. 2001. *Trends in Federal Support of Research and Graduate Education.* Stephen A. Merrill, ed. Washington, DC: National Academy Press.

National Research Council. 2003. *Government-Industry Partnerships for the Development of New Technologies: Summary Report.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2003. *Securing the Future: Regional and National Programs to Support the Semiconductor Industry.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2004. *A Patent System for the 21st Century.* Washington, DC: The National Academies Press.

National Research Council. 2004. *Productivity and Cyclicality in Semiconductors: Trends, Implications, and Questions.* Dale W. Jorgenson and Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2004. *The Small Business Innovation Research Program: Program Diversity and Assessment Challenges.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2005. *Getting Up to Speed: The Future of Superconducting.* Susan L. Graham, Marc Snir, and Cynthia A. Patterson, eds. Washington, DC: The National Academies Press.

National Research Council. 2005. *Large-Scale Biomedical Science* Washington, DC: The National Academies Press.
National Research Council. 2005. *Policy Implications of International Graduate Students and Post-doctoral Scholars in the United States*. Washington, DC: The National Academies Press.
National Research Council. 2007. *Enhancing Productivity Growth in the Information Age: Measuring and Sustaining the New Economy.* Dale W. Jorgenson and Charles W. Wessner, eds. Washington, DC: The National Academies Press.
National Research Council. 2007. *India's Changing Innovation System: Achievements, Challenges, and Opportunities for Cooperation.* Charles W. Wessner and Sujai J. Shivakumar, eds. Washington, DC: The National Academies Press.
National Research Council. 2007. *Innovation Inducement Prices at the National Science Foundation*. Washington, DC: The National Academies Press.
National Research Council. 2007. *Innovation Policies for the 21st Century.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2007. *SBIR and the Phase III Challenge of Commercialization.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2008. *An Assessment of the SBIR Program.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2008. An *Assessment of the SBIR Program at the Department of Energy.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2008. *An Assessment of the SBIR Program at the National Science Foundation.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2008. *Innovative Flanders: Innovation Policies for the 21st Century.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2008. *Innovation in Global Industries: U.S. Firms Competing in a New World.* Jeffrey T. Macher and David C Mowery, eds. Washington, DC: The National Academies Press.
National Research Council. 2009. *21st Century Innovation Systems for Japan and the United States: Lessons from a Decade of Change.* Sadao Nagaoka, Masayuki Kondo, Kenneth Flamm, and Charles Wessner, eds. Washington, DC: The National Academies Press.
National Research Council. 2009. *An Assessment of the SBIR Program at the Department of Defense*. Charles W. Wessner, ed. Washington, DC: The National Academies Press.
National Research Council. 2009. *An Assessment of the SBIR Program at the National Institutes of Health.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2009. *An Assessment of the SBIR Program at the National Aeronautics and Space Administration.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2009. *Revisiting the Department of Defense SBIR Fast Track Initiative*. Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2009. *Understanding Research, Science, and Technology Parks: Global Best Practices.* Charles W. Wessner, ed. Washington, DC: The National Academies Press.

National Research Council. 2010. *Choosing Our Nation's Fiscal Future*. Washington, DC: The National Academies Press.

National Research Council 2010. *The Dragon and the Elephant, Understanding the Development of Innovation Capacity in China and India*. S. Merrill ed., Washington, DC: The National Academies Press.

National Research Council. 2010. *Managing University Intellectual Property in the Public Interest*, Stephen A. Merrill and Ann-Marie Mazza, editors, Washington, DC: The National Academies Press.

National Research Council. 2010. *S&T Strategies of Six Countries: Implications for the United States.* Washington, DC: National Academy Press.

National Research Council. 2011. *Building the 21st Century: U.S.-China Cooperation in Science, Technology, and Innovation*. Charles W. Wessner, Rapporteur. Washington, DC: The National Academies Press.

National Research Council. 2011. *The Future of Photovoltaics Manufacturing in the United States.* Charles W. Wessner, Rapporteur. Washington, DC: The National Academies Press.

National Research Council. 2011. *Growing Innovation Clusters for American Prosperity.* Charles W. Wessner, Rapporteur. Washington, DC : The National Academies Press.

National Research Council. 2011. *Research Training in the Biomedical, Behavioral and Clinical Research Sciences*. Washington, DC.; The National Academies Press.

National Research Council. 2012. *Breaking Through: Ten Strategic Actions to Leverage Our Research Universities for the Future of America*. Washington, DC: The National Academies Press.

National Research Council. 2012. *Building Hawaii's Innovation Economy*. Charles W. Wessner, Rapporteur. Washington, DC: The National Academies Press.

National Research Council. 2012. *Rising to the Challenge: U.S. Innovation Policy for the Global Economy*. Charles W. Wessner and Alan Wm. Wolff, eds. Washington, DC: The National Academies Press.

National Research Council. Forthcoming. *Building the U.S. Battery Industry for Electric-Drive Vehicles: Progress, Challenges, and Opportunities.* Charles W. Wessner, Rapporteur. Washington, DC: The National Academies Press.

National Research Council. Forthcoming. *Clustering for 21st Century Prosperity.* Charles W. Wessner, Rapporteur. Washington, DC: The National Academies Press.
National Science Board. 2004. *Science and Engineering Indicators 2004*. Arlington, VA: National Science Foundation.
National Science Board. 2006. *Science and Engineering Indicators 2006*. Arlington, VA: National Science Foundation.
National Science Board. 2008. *Science and Engineering Indicators 2008*. Arlington, VA: National Science Foundation.
National Science Board. 2010. *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation.
National Science Board. 2011. *Science and Engineering Indicators 2011*. Arlington, VA: National Science Foundation.
National Science Foundation. 2004. *Science and Engineering Doctorate Awards: 2003*. NSF 05-300. Arlington, VA: National Science Foundation.
Needham, Joseph. 1954-1986. *Science and Civilization in China*. (Five volumes.) Cambridge: Cambridge University Press.
Nelson, R. R. 1993. *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press.
Nelson, R. R., and K. Nelson. 2002. "Technology, Institutions, and Innovation Systems." *Research Policy* 31:265-272.
Nelson, R. R., and N. Rosenberg. 1993. "Technical Innovation and National Systems." In *National Innovation Systems: A Comparative Analysis*. Richard R. Nelson, ed. Oxford, UK: Oxford University Press.
Nelson, R. R., and S. G. Winter. 1982. *An Evolutionary Theory of Economic Change*. Cambridge, MA: Harvard University Press.
Neuffer, John. 2010 "China: Intellectual Property Infringement, Indigenous Innovation Policies, and Frameworks for Measuring the Effects on the U.S. Economy." Testimony to the United States International Trade Commission Investigation. June 15.
Nishimura, Kiyohiko, G., Takanobu Nakajima, and Kozo Kiyota. 2003. "Does the Natural Selection Mechanism Still Work in Severe Recessions? Examination of the Japanese Economy in the 1990s." *Journal of Economic Behavior and Organization* 58:53-78.
Odagari, H. 1999. "University-Industry Collaboration in Japan: Facts and Interpretations." In Lewis M. Branscomb, Fumio Kodama, and Richard Florida, eds. *Industrializing Knowledge: University-Industry Linkage in Japan and the United States*. Cambridge, MA: The MIT Press.
Odagiri, H., and A. Goto. 1993. "The Japanese System of Innovation: Past, Present and Future." In R. R. Nelson, ed. *National Systems of Innovation*. Oxford, UK: Oxford University Press.
Odagiri, H., and A. Goto. 1996. *Technology and Industrial Development in Japan: Building Capabilities by Learning, Innovation and Public Policy*. Oxford, UK: Oxford University Press.

Organisation for Economic Co-operation and Development. 1999. *Boosting Innovation: The Cluster Approach*. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 1999. *Managing National Innovation Systems*. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2001. *The New Economy: Beyond the Hype—The OECD Growth Project*. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2001. *Social Sciences and Innovation*. Washington, DC: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2004. *Summary Report: Micro-policies for Growth and Productivity*. DSTI/IND(2004)7. Paris, France: Organisation for Economic Co-operation and Development. October.

Organisation for Economic Co-Operation and Development. 2008. *Main Science and Technology Indicators*. Paris: Organisation for Economic Co-Operation and Development.

Organisation for Economic Co-Operation and Development. 2008. *OECD Reviews of Innovation Policy: China*. Paris, France: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development. 2011. *Main Science and Technology Indicators*. Paris, France: Organisation for Economic Co-operation and Development.

Orszag, Peter, and Thomas Kane. 2003. "Funding Restrictions at Public Universities: Effects and Policy Implications." Brookings Institution Working Paper. September.

Oughton, Christine. 1997. "Competitiveness in the 1990s." *The Economic Journal* 107(444): 1486-1503.

Oughton, Christine, Mikel Landabaso, and Kevin Morgan. 2002. "The Regional Innovation Paradox: Innovation Policy and Industrial Policy." *The Journal of Technology Transfer* 27(1).

Owens, William, with Edward Offley. 2001. Lifting the Fog of War. Baltimore, MD: Johns Hopkins University Press. Park, W. G., and J. C. Ginarte. 1997. "Intellectual Property Rights and Economic Growth." *Contemporary Economic Policy* XV(July):51-61.

Ozgen, Ceren, et al. 2011. "Immigration and Innovation in European Regions." IZA Discussion Paper No. 5676.

Patel, P., and K. Pavitt. 1994. "National Innovation Systems: Why They are Important and How They Might Be Compared?" *Economic Change and Industrial Innovation*.

Peck, M. J., R. C. Levin, and Akira Goto. 1988. "Picking Losers: Public Policy Toward Declining Industries in Japan." In J. B. Shoven, ed. *Government Policy Toward Industry in the United States and Japan*. Cambridge, UK: Cambridge University Press. Pp. 165-239.

Peek, Joe, and Eric S. Rosengren. 2005. "Unnatural Selection: Perverse Incentives and the Misallocation of Credit in Japan." *The American Economic Review* 95(4):114-1166.

Penrose, E. 1951. *The Economics of the International Patent System*. Baltimore, MD: Johns Hopkins University Press.

Perez, Carlota. 2002. *Technological Revolutions and Financial Capital*. Cheltenham, UK: Edward Elgar.

Phan, Phillip H., and Donald S. Siegel. 2006. "The Effectiveness of University Technology Transfer: Lessons Learned from Qualitative and Quantitative Research in the U.S. and U.K." Rensselaer Working Papers in Economics 0609. Troy, NY: Rensselaer Polytechnic Institute Department of Economics.

Phan, Phillip H., Donald S. Siegel, and Mike Wright. 2005. "Science Parks and Incubators: Observations, Synthesis and Future Research." *Journal of Business Venturing* 20(2):165-182.

Phillimore, J. 1999. "Beyond the Linear View of Innovation in Science Park Evaluation: An Analysis of Western Australian Technology Park." *Technovation* 19(11):673-680.

Polenske, Karen, Nicolas Rockler, et al. 2004. *Closing the Competitive Gap: A Retrospective Analysis of the ATP 2mm Project*. NIST GCR 03-856. Gaithersburg, MD: National Institute of Standards and Technology.

Porter, M. E., 1998. "Clusters and the New Economics of Competition." *Harvard Business Review* 76(6):77-90.

Porter, M. E., and M. Sakakibara. 2004. "Competition in Japan." *The Journal of Economic Perspectives* 18(1).

Posen, Adam. 1998. *Restoring Japan's Economic Growth*. Washington, DC: Peterson Institute for International Economics.

Posen, Adam. 2001. "Japan." In Benn Steil, David G. Victor, and Richard R. Nelson, eds. *Technological Innovation and Economic Performance*. Princeton, NJ: Princeton University Press.

Powell, Jeanne, and Francisco Moris. 2002. *Different Timelines for Different Technologies*. NISTIR 6917. Gaithersburg, MD: National Institute of Standards and Technology.

President's Council of Advisors on Science and Technology. 2004. "Sustaining the Nation's Innovation Ecosystems." Washington, DC: Executive Office of the President. January.

President's Information Technology Advisory Committee. 2005. "Cybersecurity: A Crisis of Prioritization." Report to the President. February.

PricewaterhouseCoopers. 2006. "China's Impact on the Semiconductor Industry: 2005 Update." New York: PricewaterhouseCoopers.

Procassini, Andrew. 1995. *Competitors in Alliance: Industry Associations, Global Rivalries, and Business-Government Relations*. New York: Greenwood Publishing.

Purvis, G. 2002. "Moving into the Real World." *Electronic Business* July 1.

Qiang, Christine Zhen-Wei. 2004. *Contribution of Information and Communication Technologies to Growth*. Washington, DC: The World Bank.

Qiang, Christine Zhen-Wei. 2009. *Broadband Infrastructure Investment in Stimulus Packages: Relevance for Developing Countries*. Washington DC: World Bank.

Reid, T. R. 2004. *The United States of Europe: The New Superpower and the End of American Supremacy*. New York: Penguin Press.

Reiko, Yamada. 2001. "University Reform in the Post-massification Era in Japan: Analysis of Government Education Policy for the 21st Century." *Higher Education Policy* 14(4).

Reuters. 2006. "China Sees No Quick End to Economic Boom." February 21.

Rich, Ben. 1996. *Skunkworks*. New York: Back Bay Books.

Rodrik, Dani and Arvind Subramanian. 2004. "From 'Hindu Growth' to Productivity Surge: The Mystery of the Indian Growth Transition." NBER Working Paper 10376.

Romer, Paul. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98:72-102.

Rosenberg, N., and R. Nelson. 1994. "American Universities and Technical Advance in Industry." *Research Policy* 23:325-348.

Rosenzweig, R., and B. Turlington. 1982. *The Research Universities and Their Patrons*. Berkeley, CA: University of California Press.

Rothaermel, F. T., and M. C. Thursby. 2005. "Incubator Firm Failure or Graduation? The Role of University Linkages." *Research Policy* 34(7):1076-1090.

Rothaermel, F. T., and M. C. Thursby. 2005. "University-Incubator Firm Knowledge Flows: Assessing Their Impact on Incubator Firm Performance." *Research Policy* 34(3):302-320.

Rowen, Henry S., and A. Maria Toyoda. 2002. "From Kiretsu to Start-ups: Japan's Push for High Tech Entrepreneurship." Asia-Pacific Research Center Working Paper. Stanford, CA.

Ruegg, Rosalie, and Irwin Feller. 2003. *A Toolkit for Evaluating Public R&D Investment: Models, Methods, and Findings from ATP's First Decade*. NIST GCR 03-857. Gaithersburg, MD: National Institute of Standards and Technology.

Ruttan, Vernon W. 2002. *Technology, Growth and Development: An Induced Innovation Perspective*. Oxford, UK: Oxford University Press.

Ruttan, Vernon W. 2006. *Is War Necessary for Economic Growth, Military Procurement and Technology Development?* New York: Oxford University Press.

Ruttan, Vernon W. 2006. "Will Government Programs Spur the Next Breakthrough?" *Issues in Science and Technology* Winter.

Rutten, Roel, and Frans Boekema. 2005. "Innovation, Policy and Economic Growth: Theory and Cases." *European Planning Studies* 13(8).
Rycroft, Robert W., and Don E. Kash. 1999. "Innovation Policy for Complex Technologies." *Issues in Science and Technology* Fall.
Saito, Ken. 1987. *Research on a New Concern: RIKEN Industrial Group*. (In Japanese.) Jichosha
Sakakibara, M., and L. Branstetter. 2001. "Do Stronger Patents Induce More Innovation? Evidence from the 1988 Japanese Patent law Reforms." *Rand Journal of Economics* 32:77-100.
Sakakibara, M., and L. Branstetter. 2002. *Measuring the Impact of ATP-Funded Research Consortia on Research Productivity of Participating Firms, A Framework Using Both U.S. and Japanese Data*. NIST GCR 02-830. Gaithersburg, MD: National Institute of Standards and Technology.
Sakamoto, Kozo, and Masayuki Kondo. 2004. "The Analysis of University-Industry Research Collaborations by Time Series and Corporate Characteristics." (In Japanese.) *Development Engineering* 10:11-26.
Sallet, J, J. Masterman, and E. Paisley. 2009. "The Geography of Innovation." Washington, DC: Center for American Progress.
Sapolsky, Harvey M. 1990. *Science and the Navy—The History of the Office of Naval Research*. Princeton, NJ: Princeton University Press.
Saxenian, AnnaLee. 1994. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
Schaffer, Teresita. 2002. "Building a New Partnership with India." *Washington Quarterly* 25(2):31-44.
Scherer, F. M. 2001. "U.S. Government Programs to Advance Technology." *Revue d'Economie Industrielle* 0(94):69-88.
Scotchmer, Suzanne. 1996. "Protecting Early Innovators: Should Second-Generation Products Be Patentable?" *Rand Journal of Economics* 27:322-331.
Scotchmer, Suzanne. 2004. *Innovation and Incentives*. Cambridge, MA: The MIT Press.
Shane, S. 2004. *Academic Entrepreneurship*. Cheltenham, UK: Edward Elgar Publishing.
Shang, Yong. 2006. "Innovation: New National Strategy of China." Presentation at Industrial Innovation in China. Levin Institute Conference. July 24-26.
Shanghai Municipal Government. 2004. Notice of the Shanghai Municipal Government Regarding Distributing the Outline of Shanghai's Intellectual Property Strategy (2004-2010). September 14.
Shapiro, Carl. 2001. "Navigating the Patent Thicket: Cross License, Patent Pools and Standard-Setting." In Adam Jaffe, Joshua Lerner, and Scott Stern, eds. *Innovation Policy and the Economy*. Cambridge, MA: The MIT Press.
Shearmur, R., and D. Doloreux. 2000. "Science Parks: Actors or Reactors? Canadian Science Parks in their Urban Context." *Environment and Planning* 32(6):1065-1082.

Sheehan, Jerry, and Andrew Wyckoff. 2003. "Targeting R&D: Economic and Policy Implications of Increasing R&D Spending." DSTI/DOC(2003)8. Paris, France: Organisation for Economic Co-operation and Development.

Shenzhen Daily. 2005. "Nation May Introduce Antimonopoly Law." December 30.

Sherwin, Martin, and Kai Bird. 2005. *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer*. New York: Alfred A. Knopf.

Shin, Roy W. 1997. "Interactions of Science and Technology Policies in Creating a Competitive Industry: Korea's Electronics Industry." *Global Economic Review* 26(4):3-19.

Siegel, Donald S., David Waldman, and Albert Link. 2004. "Toward a Model of the Effective Transfer of Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technologies." *Journal of Engineering and Technology Management* 21(1-2):115-142.

Siegel, Donald S., P. Westhead, and M. Wright. 2003. "Assessing the Impact of Science Parks on Research Productivity: Exploratory Firm-Level Evidence from the United Kingdom." *International Journal of Industrial Organization* 21(9):1357-1369.

Simon, Dennis and Cong Cao. 2009. *China's Emerging Technological Edge: Addressing the Role of High-End Talent*. Cambridge: Cambridge University Press.

Skolnikoff, Eugene B. 1993. "Knowledge Without Borders? Internationalization of the Research Universities." *Daedalus* 122(4).

Smith, Kathlin. 1998. *The Role of Scientists in Normalizing U.S.-China Relations: 1965-1979*. Council on Library and Information Resources

Smits, Ruud, and Stefan Kuhlmann. 2004. "The Rise of Systemic Instruments in Innovation Policy." *International Journal of Foresight and Innovation Policy* 1(1/2).

Soete, Luc G., and Bastiann J. ter Weel. 1999. "Innovation, Knowledge Creation and Technology Policy: The Case of the Netherlands." *De Economist* 147(3). September.

Sofouli, E., and N. S. Vonortas. 2007. "S&T Parks and Business Incubators in Middle-Sized Countries: The Case of Greece." *Journal of Technology Transfer* 32(5):525-544.

Solow, Robert. 2000. *Growth Theory: An Exposition*. 2nd Edition. New York: Oxford University Press.

Solow, Robert. 2000."Toward a Macroeconomics of the Medium Run." *Journal of Economic Perspectives* Winter.

Spence, Michael. 1974. *Market Signaling: Informational Transfer in Hiring and Related Processes*. Cambridge, MA: Harvard University Press.

Spencer, W. J., L. Wilson, and R. Doering. 2004. "The Semiconductor Technology Roadmap." *Future Fab International* 18.

Springut, Micah, et al. 2011. "China's Program for Science and Technology Modernization: Implications for American Competitiveness." U.S.-China Economic and Security Review Commission. January.

Stanford University. 1999. *Inventions, Patents and Licensing: Research Policy Handbook*. Document 5.1. July 15.

State Council of the Peoples' Republic of China. 2006. *Outline of the National Medium- and Long-term Program on Scientific and Technological Development (2006-2020)*. February 9.

Statistics Bureau, Ministry of Internal Affairs and Communications. 2005. *Report on the Survey of Research and Development 2004*. Ministry of Internal Affairs and Communications.

Stephan, P. 2001. "Educational Implication of University-Industry Technology Transfer." *Journal of Technology Transfer* 26:199-205.

Sternberg, R. 1990. "The Impact of Innovation Centres on Small Technology-based Firms: The Example of the Federal Republic of Germany." *Small Business Economics* 2(2):105-118.

Stiglitz, Joseph. 2005. "The Ethical Economist." *Foreign Affairs*. November/December.

Stokes, Donald E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Washington, DC: Brookings Institution Press.

Strout, E. 2005. "Gift of a Book Was a Key to Intel Founder's Big Donation to City College of New York." *Chronicle of Higher Education*. December 2. P. A27.

Swann, G. M. P. 1998. "Towards a Model of Clustering in High-Technology Industries." In G. M. P. Swann, M. Prevezer, and D. Stout, eds. *The Dynamics of Industrial Clustering*. Oxford, UK: Oxford University Press.

Talele, Chitram J. 2003. "Science and Technology Policy in Germany, India and Pakistan." *Indian Journal of Economics and Business* 2(1):87-100.

Tanaka, Nobua. 2005. Presentation at the International Forum on Technology Foresight and National Innovation Strategies. Seoul, Republic of Korea. November 4.

Tassey, G. 1997. *The Economics of R&D Policy*. Westport, CT: Quorum Books.

Tassey, G. 2004. "Policy Issues for R&D Investment in a Knowledge-based Economy." *Journal of Technology Transfer* 29:153-185.

Tassey, G. 2007. *The Innovation Imperative*. Cheltenham, UK: Edward Elgar.

Teubal, Morris. 2002. "What Is the Systems Perspective to Innovation and Technology Policy and How Can We Apply It to Developing and Newly Industrialized Economies?" *Journal of Evolutionary Economics* 12(1-2).

Thelin, J. 2004. *A History of American Higher Education*. Baltimore, MD: Johns Hopkins University Press.

Thomas, J. R., and W. H. Schacht. 2008. "Patent Reform in the 110th Congress: Innovation Issues." Report for Congress. Washington, DC: Congressional Research Service. Order Code RL33996.

Thursby, J., and M. Thursby. 2002. "Who is Selling the Ivory Tower? Sources of Growth in University Licensing." *Management Science* 48:90-104.

Thursby, J., and M. Thursby. 2004. "Industry Perspectives on Licensing University Technologies: Sources and Problems." *AUTM Journal* P. 2000.

U.S. Congress. 1988. *Omnibus Trade and Competitiveness Act of 1988* (P.L. 100-418, codified in 15 U.S.C. 278n.) and later amended by the *American Technology Preeminence Act of 1991* (P.L. 102-245, codified in 15 U.S.C. 3701).

U.S. Department of Commerce. 2008. *Innovation Measurement: Tracking the State of Innovation in the American Economy, Report to the Secretary*. Washington, DC: U.S. Department of Commerce. January.

U.S. General Accounting Office. 2002. *Export Controls: Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental U.S. Policy Review*. GAO-020620. Washington, DC: U.S. General Accounting Office. April.

U.S. Small Business Administration. 2004. "Small Business by the Numbers." Office of Advocacy. Washington, DC: U.S. Small Business Administration. June.

Vaidyanathan, G. 2008. "Technology Parks in a Developing Country: The Case of India." *Journal of Technology Transfer* 33(3):285-299.

Van Atta, Richard. 2004. "Energy and Climate Change Research and the DARPA Model." Presentation to the Washington Roundtable on Science and Public Policy. November 3.

Van Atta, Richard. 2008. "Fifty Years of Innovation and Discovery." In *DARPA: 50 Years of Bridging the Gap*. Arlington, VA: Defense Advanced Research Projects Agency. April.

Van Atta, Richard, and Michael Lippitz. 2003. *Transformation and Transition: DARPA's Role in Fostering an Emerging Revolution in Military Affairs*. Volume 1: Overall Assessment. Alexandria, VA: Institute for Defense Analysis.

Van Atta, Richard, et al. 1991. *DARPA Technical Accomplishments*. Volumes I-V. Alexandria, VA: Institute for Defense Analysis.

Van Atta, Richard, et al. 1991. *DARPA Technological Accomplishments: An Historical Review of Selected DARPA Projects*. Alexandria, VA: Institute for Defense Analysis.

Van Looy, Bart, K. Debackere, and T. Magerman. 2005. *Assessing Academic Patent Activity: The Case of Flanders*. Leuven, Belgium: SOOS.

Van Looy, Bart, Marina Ranga, Julie Callaert, Koenraad Debackere, and Edwin Zimmermann. 2004. "Combining Entrepreneurial and Scientific Performance in Academia: Towards a Compounded and Reciprocal Matthew-effect?" *Research Policy* 33(3):425-441.

Vedovello, C. 1997. "Science Parks and University-Industry Interaction: Geographical Proximity between the Agents as a Driving Force." *Technovation* 17(9):491-502.

Vest, C. 2005. "Industry, Philanthropy and Universities-The Roles and Influences of the Private Sector in Higher Education." 2005 Clark Kerr Lecture. University of California at Berkeley. September 13.

Wadhwa, Vivek, and Gary Gereffi. 2005. *Framing the Engineering Outsourcing Debate*. Durham, NC: Duke University.
Walcott, Susan M. 2003. *Chinese Science and Technology Industrial Parks*. Aldershot, UK: Ashgate Publishing.
Waldrop, M. Mitchell. 1992. *Complexity: The Emerging Science at the Edge of Order and Chaos*. New York: Simon & Schuster.
Waldrop, M. Mitchell. 2001. *The Dream Machine*. New York: Viking Press.
Wall Street Journal. 2010. "Loan Squeeze Thwarts Small-Business Revival." March 15.
Walsh, J. P., and W. M. Cohen. 2004. "Does the Golden Goose Travel? A Comparative Analysis of the Influence of Public Research on Industrial R&D in the U.S. and Japan." Mimeo.
Wang, Liwei. 1993. "The Chinese Traditions Inimical to the Patent Law." *Northwestern Journal of International Lawand Commerce* Fall.
Warsh, David. 2006. *Knowledge and the Wealth of Nations*. New York: W. W. Norton.
Wiener, Norbert. 1948. *Cybernetics or Control and Communication in the Animal and the Machine*. Cambridge, MA: The MIT Press.
Wen, Jiang, and Shinichi Kobayashi. 2001. "Exploring Collaborative R&D Network: Some New Evidence in Japan." *Research Policy* 30:1309-1319.
Wessner, Charles W. 2005. "Entrepreneurship and the Innovation Ecosystem." In David B. Audretsch, Heike Grimm, and Charles W. Wessner, eds. *Local Heroes in the Global Village: Globalization and the New Entrepreneurship Policies*. New York: Springer.
Westhead, P. 1995. "New Owner-Managed Businesses in Rural and Urban Areas in Great Britian: A Matched Pairs Comparison." *Regional Studies* 29(4):367-380.
Westhead, P., and D. Storey. 1997. "Financial Constraints on the Growth of High-Technology Small Firms in the U.K." *Applied Financial Economics* 7(2):197-201.
Westhead, P., and M. Cowling. 1995. "Employment Change in Independent Owner-Managed High-Technology Firms in Great Britain." *Small Business Economics* 7(2):111-140.
Westhead, P., and S. Batstone. 1998. "Independent Technology-based Firms: The Perceived Benefits of a Science Park Location." *Urban Studies* 35(12):2197-2219.
World Bank. 2004. *Innovation Systems: World Bank Support of Science and Technology Development*. Vinod Kumar Goel, ed. Washington, DC: World Bank.
World Bank. 2006. *The Environment for Innovation in India. South Asia Private Sector Development and Finance Unit*. Washington, DC: World Bank.
World Bank International Finance Corporation. 2006. *Doing Business in 2006: Creating Jobs*. Washington, DC: International Bank for Reconstruction and Development.

World Trade Organization Working Party on the Accession of China. 2001. *Report of the Working Party on the Accession of China*. WT/MN(01)/3. November 10.

Wu, Ching. 2006. "China to Build 30 New Science and Technology Parks." *SciDev.net*. April 19.

Yan, Dai. 2004. "Anti-Monopoly Legislation on the Way." *China Daily* June 18.

Yoshida, Fujio. 1967. "Preparation of Legal System for Capital Liberalization (Part 3)." Panel Discussion in Zaikei Shoho. July 17.

Yoshida, Junko. 2006. "Grenoble Lure: Un-French R&D." *EE Times* June 12.

Young, John. 2007. Info Memo for Secretary of Defense Robert M. Gates. DoD Science and Technology Program. August 24.

Yukio, Sato. 2001. "The Structure and Perspective of Science and Technology Policy in Japan." In Phillipe Laredo and Phillipe Mustar, eds. *Research and Innovation Policies in the New Global Economy: An International Comparative Analysis*. Cheltenham, UK: Edward Elgar.

Zachary, G. Pascal. 1999. *Endless Frontier: Vannevar Bush, Engineer of the American Century*. Cambridge, MA: The MIT Press.

Zeigler, Nicholas J. 1997. *Governing Ideas: Strategies for Innovation in France and Germany*. Ithaca, NY: Cornell University Press.

Zemin, Jiang, General Secretary of the Communist Party of China Central Committee. 1999. Keynote Speech at the National Technological Innovation Conference, August 23.

Zhang, Chunlin, Douglas Zhihua Zeng, William Peter Mako, and James Seward. 2009. *Promoting Enterprise-Led Innovation in China, 2009*. Washington, DC: The International Bank for Reconstruction and Development/The World Bank.

Ziedonis, R. H., and B. H. Hall. 2001. "The Effects of Strengthening Patent Rights on Firms Engaged in Cumulative Innovation: Insights from the Semiconductor Industry." In Gary Libecap, ed., *Entrepreneurial Inputs and Outcomes: New Studies of Entrepreneurship in the United States*. Volume 13 of *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*. Amsterdam, The Netherlands: Elsevier Science.