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AICGS POLICY REPORT

PART ONE: INNOVATION IN THE UNITED STATES AND GERMANY

Kent Hughes
Axel Werwatz

AMERICAN INSTITUTE FOR CONTEMPORARY GERMAN STUDIES THE JOHNS HOPKINS UNIVERSITY

AICGS

AMERICAN INSTITUTE FOR CONTEMPORARY GERMAN STUDIES

THE JOHNS HOPKINS UNIVERSITY

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FOREWORD

As economic ties between the United States and Germany have grown steadily deeper and more intertwined, economic performance in one country increasingly affects the transatlantic partnership as a whole. Positive economic growth and strong economies have a number of underlying factors, one of which is a climate of innovation, which itself is influenced to varying degrees by the quality of educational systems, a society's tolerance for risk, and various political, cultural, social, historical, and institutional factors.

This publication is the first in a three-part series titled, "Advancing Innovation, Enhancing the Economy: A German-American Project," which will look closely at the importance of innovation for the global economic competitiveness of the United States and Germany. The essays in this AICGS Policy Report explore the history of innovation in the United States and Germany, identifying and assessing the impact of cultural, historical, and institutional factors on the innovation process in these two countries. In their essays, Kent Hughes and Axel Werwatz seek to identify and address the broad range of factors that affect competitiveness and adaptation to the global economy as it relates to innovation. These essays also provide a foundation for exploring broader questions in relation to innovation, such as: How innovative are the U.S. and German economies—at both the macro and micro (firm) levels, compared with their innate potentials and their developing country counterparts? Is there a set of "best practices" against which the performance of these two partners can be measured and evaluated vis-à-vis the other, and how can "best practices" be adapted to the unique institutional, cultural, or historical context of each country while still remaining effective? How can the United States and Germany learn from each other, and what steps should be taken by the two sides over the medium term to help facilitate such learning?

For the United States and Germany, two pillars of the global economy, as well as for other EU members, encouraging technological innovation may prove the key to ensuring continued gains in productivity. Absent such an impulse, the U.S. economy could once again—as it did in the late 1960s and throughout the 1970s—return to a low-growth path. Fostering healthy innovation is perhaps even more vital for Germany than for the United States. Underlying dynamics of exploding social expenditures, spiraling deficits, and an aging population, combined with a dramatic shift in the global terms of trade in favor of low-cost Asian producers, have contributed to the virtual stagnation, if not outright decline, of the German economy. A more favorable environment in support of innovation will not, in itself, rescue the German economy from its decade-long depression; its absence, however, will virtually guarantee another several decades of economic and social malaise.

This project is undertaken as part of the AICGS Economics Program, which seeks to generate insights into the institutional, political, cultural, and historical factors that shape responses to deepening economic integration and the challenges of globalization. Through these three Policy Reports on innovation, AICGS seeks to enhance understanding of the broader context in which the process of innovation unfolds, as well as the role of policy and government regulation in promoting or hindering innovation. Previous AICGS reports have focused on breaking down barriers to trade and investment. Likewise, a major focus of this project is to identify structural barriers to technological innovation and what steps might be taken to ameliorate, if not entirely remove them, at the national and international levels.

We are grateful to the Gillette Businesses of the Proctor and Gamble Company for their support of this project and series of publications. We would also like to thank Jim Kilts for his encouragement and guidance.

Jackson Janes
Executive Director
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CHAPTER ONE
INNOVATION IN THE UNITED STATES

INNOVATION IN THE UNITED STATES: THE INTERPLAY OF HISTORY, INSTITUTIONS, AND AMERICAN CULTURE

KENT HUGHES

America's innovation system was not the product of a single grand design. At the turn of the twentieth century, there was no single national body that planned the extensive network of federal laboratories, decided on the need for large, research-oriented universities, or created a venture capital market. Instead, in response to the pressure of a crisis or the power of a new vision, the country took various steps that created a diversity of institutions that eventually became a system supportive of innovation.

Despite the lack of an original comprehensive design, American national laboratories, research universities, and private companies have discovered and exploited the potential synergies created by their interaction. A more self-conscious effort to create new institutions that would sustain basic scientific research was made after World War II. In the 1980s, when the public and private sectors needed to respond to increasing competition from Germany and Japan, Congress adopted a series of policies designed to speed the transfer of university and research-laboratory technologies to the market.

By virtually any measure, the second half of the twentieth century marked an enviable period in the history of American innovation. Whether measured by the number of Nobel Prizes awarded, patents issued, or scientific articles published in scholarly journals, the United States stood out as a world leader in the innovation field. Whether the United States can retain this position in the globally competitive twenty-first century environment remains to be seen.

What contributed to the pace of American innovation in the late twentieth century? The following essay attempts to answer that question by looking at the history of innovation in the United States, the institutions that have fueled scientific and technological progress, and the underlying cultural traits that support America's continuing search for the next frontier.

The History of Innovation in America

The history of innovation in America can be traced back to the earliest days of the Republic. Article I, Section 8 of the U.S. Constitution gave Congress the "Power to promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." Article I, Section 8 gave rise to the system of patents, copyrights, and trademarks presently protecting American innovations. While today's U.S. government promotes international recognition of intellectual property rights, this was not always the case. Many eighteenth and nineteenth century American industrialists copied the trade secrets of British industry, which was the world economic leader at the time. In fact, until 1836 most foreigners could not receive a patent in the United States;[1] copyright protection for foreign works was not granted until 1891.[2]

The steady westward expansion of the United States during the first half of the nineteenth century created new opportunities for innovation. Public support for investment in infrastructure began with roads and canals, which later contributed to the creation of a continental economy, which in turn created an ample market for new technologies. The innovations themselves were the product of individual inventors partnering with entrepreneurs. Foreign capital, particularly from Britain, helped fuel the American economy and, in that sense, helped to support American innovation.

In the nineteenth century, the United States also became a global leader in the adoption of a universal education system and philosophy. This emphasis on education continued into the twentieth century, accelerating after World War II through the adoption of the GI Bill, which supported education for returning soldiers; the expansion of state universities; and the imitation of the 'California Model' education system, which included major research universities, state colleges, and two-year community (in some cases junior) colleges.

Opportunity and necessity were the twin forces behind much pre-World War II research done in the United States. The opportunities for unprecedented growth in the agricultural sector, coupled with a limited labor force, helped focus research on labor-saving, land-intensive innovations. In the midst of the American Civil War (1861-1865), the United States took a major step toward creating a systematic approach to research: the 1862 Morrill Act[3] created a system of land-grant colleges to promote the "agricultural and mechanical arts." To this day, many major public universities retain "A&M" (agricultural and mechanical) as part of their name.

Subsequent legislation, such as the 1887 Hatch Act and the 1907 Adams Act, established experimental agriculture centers in individual states.[4] The development of an extension service to bring the latest agricultural techniques to individual farmers was also strongly emphasized. By the twentieth century, land grant colleges did agricultural research, helped teach farmers how to make use of the research, and provided innovations that could be distributed through the extensions system. Innovations in the food-processing industry and in farm equipment made U.S. agriculture even more productive. In a sense, America's first successful experience with industrial policy was in agriculture. The adoption and more aggressive prosecution of American anti-trust laws in the late nineteenth and early twentieth century acted as a spur to industrial research. Increasingly limited in their ability to collude over price controls, large companies were forced to seek horizontal mergers and later turned to industrial research to further their growth. Patents were publicly sanctioned pathways to at least temporary monopoly power.[5]

Military spending and the imperatives of war also spurred innovation throughout U.S. history. The American Civil War gave rise to numerous innovations, including the widespread adoption of interchangeable parts in machinery. After World War I, the federal government took a more active role in stimulating military innovation. Fearing that U.S. forces had fallen behind their European counterparts in terms of radio communications, the U.S. government forced a pooling of relevant patents to help start what became the Radio Corporation of America (RCA). In its early phase, the U.S. Navy held a significant portion of RCA shares, which demonstrated the willingness of the U.S. government to intervene actively in industrial markets when national security was at risk.

World War I also provided a major boost for U.S chemical and pharmaceutical companies. In 1914, Germany was a global leader in both industries. Famous for the phrase "chemicals not colonies,"[6] German industry had developed a dominant position in Europe and already established a base in the United States. However, after the outbreak of hostilities between the United States and Germany, the U.S. government seized patents held by German chemical and pharmaceutical firms and transferred them to American ownership.[7] Developments such as these laid a basis for future progress in innovation, but it was World II and the Cold War that transformed a largely company-based system supported by government regulations into the major innovation enterprise that characterizes the American economy in the early days of the twenty-first century.

Institutions and Innovation

Since the end of World War II, the American innovation system has gone through three stages: the end of the war into the early 1970s; the 1970s/1980s response to German and Japanese competition; and what some call the 'roaring nineties.' Throughout these stages, the American innovation system was never simply a collection of talented scientists huddled in a laboratory. It was and remains the product of a combination of public and private institutions, large and small businesses, and a supporting financial system that starts with so-called "angel investors" and encompasses everything from public pension funds to private equity funds. Innovation in the United States is further supported by a large educational enterprise that develops domestic talent and has also attracted millions of future scientists and engineers from around the world.

PHASE I: THE END OF WORLD WAR II TO THE COMPETITIVENESS CHALLENGE OF THE 1970s

In an early twenty-first century characterized by global just-in-time inventory management, the Internet, and deepening interdependence among states, it is easy to forget how economically independent the United States was six decades ago. At the end of World War II, the United States produced roughly 50 percent of the world's gross domestic product and held an estimated 80 percent of the world's hard currency reserves. Had President George W. Bush been speaking in 1946 instead of 2006, he could not have announced that "America is addicted to oil"[8]—at the time, the United States was a net exporter of oil.

Just a few decades ago, the American manufacturing economy was dominated by a few prominent firms in every industry. The competition among those few could be fierce—older readers will remember the battles between General Electric and Westinghouse for control of the home appliance and electronics markets. The automobile industry, which started out as several smaller firms, underwent a gradual consolidation. General Motors was so dominant that by the 1950s, it feared garnering 50 percent of the American auto market, a figure the company thought might result in an anti-trust action to break up the corporation. In contrast, today's American and international financial press openly speculate about whether or not General Motors is headed for bankruptcy.

The widely shared view that science had helped win World War II was an early source of support for expanded federal funding of research. The onset of the Cold War in the late 1940s sharply reversed the initial decision following World War II to demobilize much of the American military and gave added impetus to defense spending, including funds targeted at both basic research and at developing new technologies, in particular those focused on national security. In 1950, the Cold War turned hot with the start of the Korean War. Military spending remained high even after the armistice in 1953 brought an end to open hostilities. When President Kennedy was sworn into office in 1961, military spending hovered around 10 percent of the country's gross domestic product (GDP). Even with the sharp build-up under President George W. Bush, military spending rose to only roughly 4 percent of GDP as of the early 2000s.

Energy, Defense, and Health

The Manhattan Project, which created the world's first atomic bomb, spawned a number of national energy labs dedicated to the development, production, and safeguarding of what became an enormous stockpile of nuclear weapons. The opportunity to pursue path-breaking research and the added sense of a national mission attracted many of the best scientists to these labs. Periodic assessments of the laboratories found that the knowledge and expertise of their personnel matched that of the brightest minds at the best universities in the United States, and that the labs had superior equipment as well.

The atomic bomb was developed at Los Alamos Laboratory in New Mexico, which was founded in 1943. Today, Los Alamos remains a major energy laboratory. Los Alamos was joined in 1949 by the Sandia Laboratory in New Mexico and, later, by the Lawrence Livermore Laboratory in California. These were followed by labs at Argonne (Illinois), Oak Ridge

(Tennessee), and Ames (Iowa), among others. The labs' initial focus on nuclear weapons supported funding for extensive research on particle physics and a number of other scientific disciplines. In response to more recent national imperatives, these energy labs have dramatically broadened their focus from nuclear weapons, now conducting research on everything from economic security to environmental management. Today, the laboratories have some 30,000 employees and combined budgets worth billions.

Like the energy labs, the Department of Defense (DoD) was also looking for new technologies for better weapons following World War II. That meant significantly more research. While DoD research and development budgets were heavily tilted toward the testing of new weapons, there was significant funding for basic and applied research, now referred to as the 6.1 and 6.2 accounts, respectively.

The impact of the Department of Defense extended well beyond increased funding for basic research. DoD often set demanding standards that hastened the development of new technologies, some of which would later have commercial applications. The DoD's practice of opening purchases to all companies under a bidding system provided a significant boost to small start-up companies.[9] In many cases, the DoD or one of the military services not only funded the research, but was also the critical first customer for a number of key technologies in the electronics field, such as the vacuum tube during World War I, the solid state diode, the transistor, the integrated circuit, and the computer.[10]

The National Institutes of Health was also transformed as a result of World War II and its aftermath. What started in 1887 as a single one-person laboratory inside the Marine Hospital Service gradually grew into a research institution inside the Public Health Service and, later, the National Institutes of Health. Legislative action toward the end of World War II created and then expanded a grants program that became the major vehicle for funding basic research in the life sciences. Today, some 80 percent of the almost $28 billion 2006 budget is devoted to research grants.

The American University System

American universities played a critical role in the post-World War II innovation system. Even before the war, these institutions began to improve their capacity for basic research. For instance, American work in physics was beginning to match the caliber of work being done in Europe on the subject even before the late 1930s flood of European refugees brought a surge of academic talent to the United States.[11] Like most American institutions, the universities were deeply involved in the war effort and affected by their role in it. Shortly after Congress declared war in 1941, the Association of Land-Grant Colleges offered the country "all of their facilities for…professional training and research."[12] Throughout the war, universities were actively involved in research and training with the military services.

The real transformation of the American university came in the aftermath of the war. Returning veterans flowed into universities on a tide of money provided by the G.I. Bill. As industry shifted from military to civilian production, universities worked to provide the technical and engineering talent demanded by a rapidly growing economy. Universities became home to most of the basic research in the life and physical sciences. Compared to universities in other parts of the world, the American university did more to prepare students for life outside the university. While there was always a love of "art for art's sake" within the institution, the American university never developed an antipathy towards business. The sentiment was not, however, "art for the sake of profit"; rather, the sense prevailed that universities were contributing to progress in a still-developing nation.

The wave of veterans was followed by the baby-boom and an enormous expansion of opportunities for higher education. While higher education was not focused exclusively or even principally on science and engineering, the expansion of state-based institutions created a structure that could effectively utilize federal dollars earmarked for funding research and grow through the later expansion of federal support for undergraduate and graduate education. Many states eventually emulated the California system, combining a number of top research universities with state colleges and two-year community colleges. The community colleges were initially seen as low cost, easily accessible stepping stones to a four-year degree.

In addition to universities, industry labs would also prove to be major sources of innovation. The best known is still Bell Labs. Popularly charged with being a monopoly, the American Telephone and Telegraph Company (AT&T) established Bell Labs to demonstrate its commitment to continued innovation. Shielded from most competition in the post-World War II era until partial divestiture in 1984, Bell Labs became a font of discovery, producing six Nobel Prize winners and trail-blazing innovations.[13]

American Finance

The evolving American financial structure also played an important role in fostering and sustaining innovation and continues to do so. In American politics, it is common to hear the phrase "money is the mother's milk of politics." The phrase applies equally to many aspects of the American economy, including innovation.

The post-World War II emergence of a venture capital industry provided early investment funds for risk-taking, innovative firms. While wealthy American families had created pools of money that did fund some important ventures, American Research and Development (ARD) was the first independent fund taking equity stakes in such still privately-held, high-growth companies. ARD was founded in 1946 by the president of MIT, a Harvard Business School professor, and local business leaders—perfect symbols for the kind of American collaboration that has developed since the middle of the twentieth century. ARD was constructed as a publicly traded closed-end fund, a structural form that dominated venture capital firms up through the 1970s. The first venture capital firm established as a limited partnership was started in 1958; this became the more common structure in the 1980s.

Venture capital firms were not the only source of funding for high-risk enterprises.[14] American entrepreneurs often raised funds from family and friends. Wealthy individuals, often referred to as "angel investors," also provided some start-up funds. When the U.S. Department of Labor changed its "prudent man rule" to allow pension funds to invest a limited portion of their capital in riskier ventures, they became a significant source of venture capital. University endowment funds eventually followed. During what can be called the first American competitiveness era—roughly the late 1970s through the 1990s—large manufacturing firms developed their own in-house venture capital funds.

The Space Race and the National Defense Education Act

In 1957, the Soviet Union shocked America by putting the first human-made satellite, named Sputnik, into orbit around the Earth: America had lost the race to space.[15] The Soviet triumph was widely seen as a threat to U.S. national security and was certainly taken as an enormous blow to American pride. The event triggered a national reaction ranging from President Kennedy's commitment to put a man on the moon before the end of the decade to local school boards' determination to improve the teaching of mathematics, science, and foreign languages.[16]

Determination to take back the lead in space exploration further shaped and strengthened the American innovation system. Since World War I, the United States had pursued aeronautical research and supported aviation through the National Advisory Committee on Aeronautics (NACA). In the wake of Sputnik, President Eisenhower established the National Aeronautics and Space Administration (NASA), which absorbed the NACA. NASA became an additional source of research funds, principally in the physical sciences, but it was not the only source of such funds. Throughout the 1960s, a sharp increase in federal funding for research-based programs paralleled the growing importance of research for the corporate world. The space program, however, was much more than a reason to increase research funding: the race to the moon caught the fancy of an entire generation of young Americans. Today, if a sixty-year-old scientist or engineer is asked what drew them into a scientific career, the answer is often the space-race.

The Soviet leap into space also focused American attention on Soviet success in producing scientists and engineers. There was a widespread sense that American education was not keeping pace with the needs of a scientific age. One result of this concern was the National Defense Education Fellowship, which funded post-graduate study in a number of sciences, including economics, and also supported study of a foreign language deemed critical to the future well-being of the United States, such as Russian or Chinese, in conjunction with another discipline.

Sputnik also led to a lasting change in the structure of research in the Department of Defense. With the intent of coordinating the military's efforts in space-related research, President Eisenhower agreed to the creation of the Advanced Research Projects Agency (ARPA).[17] The agency was to operate independently of the individual military services, with guidance from the Office of the Secretary of Defense. Although space-related research was the initial impetus for the agency's creation, in its founding language, ARPA was also charged with research and development pertaining to "weapons systems and military requirements."[18] ARPA, now renamed the Defense Advanced Research Projects Agency (DARPA), continues to fund risky projects with potential military applications.

While not intended to create a system, the American focus on space, research, and education in the 1960s had a synergistic effect. President Kennedy's emphasis on the space-race made effective use of the bully pulpit to draw young Americans into scientific careers. National need and national funding matched the growing interest in science and engineering. The federal government essentially helped to create a future supply of scientists, while at the same time creating the research demand needed to turn popular interest in science into promising careers in the aeronautics and defense fields.

Defense, Universities, Entrepreneurs, and Clusters of Innovation

Defense spending on research, the growth of the research university, the development of leading American firms in the electronics field, and the entrepreneurial streak in the American character interacted in a way that led to regional concentrations or clusters of innovation. In the 1960s, Route 128 around Boston and Silicon Valley south of San Francisco emerged as hot beds of innovation. These areas had some notable characteristics in common. Both regions had attracted DoD research money and both developed major electronics firms. Both were built around major research universities—MIT and Harvard for Route 128, and Stanford and University of California, Berkeley, in Silicon Valley. MIT and Stanford were oriented toward working with industry and facilitating the flow of talent and ideas from the academic to the industrial world. The universities were not only a constant font of new ideas, but also provided their respective regions with a steady flow of the best scientific talent.

Silicon Valley was characterized by an abundance of start-up companies, which were often founded by scientists and engineers previously affiliated with larger companies. Fairchild Semiconductor, one of Silicon Valley's first start-ups, has been referred to as the father of Silicon Valley: "Between 1959 and 1979…Fairchild…spawned 50 new high tech companies in Silicon Valley."[19] As Silicon Valley developed, large companies would often acquire smaller firms with a history of successful innovative ideas. In the 1980s and 1990s, leading firms took the additional step of developing their own venture capital funds to support start-ups that could in turn support the larger firm's core mission or commercialize technologies developed in their laboratories that fell outside the strengths of the parent firm.

Route 128, however, took a different path. Rather than developing a network of start-ups, the firms on Route 128 tended to look at internally generated growth. Unlike the fluid, constantly changing networks of Silicon Valley, Route 128 firms emphasized secrecy, loyalty, and a more traditional hierarchy in the firm. The Route 128 approach worked well in stable conditions, but they proved less able to respond to shifting technologies and the reduction in military spending in the early 1990s. Eventually, Route 128 ceded its prominence in computer technologies to Silicon Valley.[20]

PHASE II: RESPONDING TO STAGFLATION AND THE CHALLENGE FROM JAPAN

Like World War II and the shock of Sputnik, the twin challenges of 1970s stagflation and rising international competition had a significant impact on the American innovation system. The transformation of American innovation at this time started with a search for new economic ideas to stimulate productivity growth, control inflation, and match the price, quality, and pace of innovation challenging America from overseas. Again, virtually every actor in the system—the federal government, the private sector, universities, and state governments—would be affected. The government adopted policies to speed the commercialization of new technologies and create an environment favorable to innovation, key elements in what came to be called a national competitiveness strategy. The private sector worked on a parallel path by shifting research from corporate labs to business units and emphasizing rapid development and deployment of new technologies. Universities worked more effectively with the private sector by, for example, establishing incubators—facilities that could house start-up businesses attempting to commercialize university-generated innovations—to help turn academic research into a competitive business.

Federal Action: The Search for New Ideas

Starting in the late 1970s, both Houses of Congress considered a variety of new policies ranging from caucuses focused on the importance of boosting exports, to industrial policies targeted at both old and emerging industries, to adopting the supply-side school of economics' emphasis on the incentive power of reductions in marginal tax rates.

A much more direct and powerful impact on innovation, however, was the result of yet another approach. Emphasizing the importance of long-term productivity growth, the competitiveness school of thought responded to both the problem of stagnating productivity growth and to the need to meet the challenge of international competition, particularly from Japan. By the mid-1980s, the Japanese appeared to be successfully advancing to a level of industrial dominance capable of challenging not only the American economy, but also the American system of doing business. In place of open markets, Japan practiced a complicated form of trade protectionism. The government intervened in markets and worked closely with businesses instead of acting only as a rule-setting referee.

In the 1980s, Congress and three presidents took a series of steps to make the American innovation system more responsive to international competition. The first step was taken in 1980 under the Stevenson Wydler Technology Innovation Act, which allowed federal laboratories to transfer federally owned technologies to state and local governments and the private sector.[21] The same year saw the adoption of the Bayh-Dole University and Small Business Patent Act, designed to facilitate the transfer of federally-funded university research to the private sector. The Small Business Innovation Development Act of 1982 directed agencies with significant research budgets to set aside a percentage of those budgets for the support of small high-tech companies with commercial potential. Operating as the Small Business Innovation and Research Program (SBIR), the program has grown in size and increased its emphasis on commercial potential in addition to technical merit.

Additional steps in the 1980s facilitated business-to-business collaboration by reducing the extent of antitrust penalties,[22] allowing Cooperative Research and Development Agreements between business and federal laboratories, [23] and allowing business collaboration with national laboratories operated by individual contractors.[24]

The Omnibus Trade and Competitiveness Act of 1988 took two different approaches to strengthening the innovation system. First, it created the Advanced Technology Program (ATP) to fund the development of high-risk, high-payoff technologies, generally on a matching basis with private industry. ATP, however, has proven to be controversial with the George W. Bush administration, which has attempted to terminate the program. Congress, however, has insisted on maintaining at least some level of funding.[25]

In addition to the ATP, the Omnibus Act of 1988 created the Manufacturing Extension Partnership program (MEP), designed to bring technologies and improved business practices to small- and medium-sized manufacturers. Strongly supported by the Clinton Administration, the MEP has grown into a program with nearly 350 locations partnering with industry and state and local governments.

In an era marked by tax incentives, research was not neglected. Starting in 1981, Congress adopted a Research and Experimentation Tax Credit to stimulate additional research in the private sector. The R&E Tax Credit has been periodically modified upon its renewal but has never been made permanent. The credit lapsed at the end of 2005, but in his 2006 State of the Union Address, President Bush again called for the credit to be made permanent.[26]

Certain themes ran through the federal government's support for a more active technology policy in the 1980s. First, there was an attempt to enable the formation of links among business, national laboratories, and universities—all with an eye to building on existing strengths while also responding to the Japanese pace of bringing innovations to market. Second, there was a strong emphasis on small business that not only fit the American celebration of the entrepreneur, but also recognized the role small start-ups played in the overall innovation system. Finally, with initiatives such as Cooperative Research and Development Agreements, the SBIR program, the ATP, and the MEP, the federal government took steps to become a pragmatic partner of the private sector in developing new technologies.

In the late 1980s, there was widespread concern that the United States could lose its standing as a leader in the manufacture of semiconductors; the industry was viewed as critical for national defense and for the country's economic future, but was being battered by Japanese competition. At the time, semiconductors were often described as the crude oil of the late twentieth century. In 1987, the leading U.S. manufacturers of semiconductors formed SEMATECH, a consortium designed to strength the U.S. semiconductor industry. Congress provided funds for the consortium and the Department of Defense under the Reagan administration contributed half of the annual $500 million budget. The establishment of SEMATECH was another example of how pragmatism and institutional flexibility overcame a market-biased ideology that eschewed industrial policy. The formation of SEMATECH was preceded in 1986 by the imposition of dumping duties (i.e. additional tariffs) on Japanese semiconductor exports to the United States and a Japanese commitment to open at least a portion of its semiconductor market to non-Japanese semiconductor imports, which were expected to come mostly from the United States.

The federal role was also important for industries facing more competition from Europe than Japan. For instance, federal funding for medical research provided significant support for the U.S. pharmaceutical industry. And like the electronics industry and software firms, pharmaceutical companies drew on the prowess of small start-up companies, particularly as bio-technology became an important factor in medical innovation. The pharmaceutical industry also benefited from the policy innovations of the 1980s, including their use of the Research and Experimentation Tax Credit and the SBIR program.

The Private Sector

Responding to the pressure of Japanese competition, many companies closed their central labs and or dispersed them to operating units. Shifting the emphasis from the research to the development side and from central laboratories to operating units did speed the introduction of new, competitive products. There was, however, a significant loss in terms of the overall innovation system. Starting with the court-mandated breakup of AT&T in 1984, Bell Labs has come under ever greater pressure to move from basic research to research designed to deliver more immediate, more tangible benefits to its current owner, Lucent Technologies.[27] Students and makers of U.S. technology policy are aware of this shift in the nature of corporate R&D. Many describe the resulting gulf between basic university-style research and the now more limited approach to business research as a "valley of death" threatening the process of translating breakthrough work into commercial, growth-stimulating, job-creating products.

The States

The states in the U.S. federal system have long played an important role in providing many of the conditions necessary for an innovative economy.[28] Most of the spending on K-12 education is done at the state or local level. State support of institutions of higher learning remains important, with some large state universities ranking among the top research universities in the world. In recent years, states have also shifted their efforts away from courting low-skill, low-wage industries towards attracting innovative firms that produce higher value-added, high-technology goods that produce better-paying jobs.[29] Tax rates and subsidies can be still be important in attracting firms, but states also compete through the quality of local schools and the availability of a university system that allows engineers to maintain and improve their skills.

Universities

By giving universities or their professors ownership of the results of federally supported research—the purpose of legislation such as the Bayh-Dole Act—the government encouraged universities to create offices to facilitate the transfer of technologies to the private sector. Universities also created incubators for start-up businesses attempting to commercialize university-generated innovations.

PHASE III: A RESURGENT AMERICA

In the 1990s, the George H.W. Bush and Clinton administrations applied the competitiveness strategy with extremely good results. They worked to create a macroeconomic environment that encouraged new investments, which often incorporated process innovations. Active export promotion was wedded to an ongoing effort to open markets around the world. The expected emphasis on education and training became a policy favoring life-long learning aimed at keeping pace with advances in technology and the development of new industries.

The latter effort included not only persistent use of the bully pulpit—President Clinton frequently reminded Americans that they lived in a world where they will hold several jobs over the course of their working lives—but added a number of programs that facilitated training of the incumbent workforce. President Clinton stressed in particular the importance of an active technology policy that included everything from reducing restrictions on exports of high technology items to active support for technology programs ranging from manufacturing extension centers to a focus on reducing pollution and energy use through the Partnership for a New Generation of Vehicles.

Several other elements complemented the adoption of a competitiveness strategy. In order to compete more effectively with efficient Japanese companies, much of American industry had adapted Toyota's lean production technique—production lines focused on quality, as-needed inventory, minimal middle-management, and integrated plans for design and manufacturability—to their own industries and circumstances. Just as American industry was poised to invest in new capacity, the Internet and information technology in general were offering tremendous possibilities. The Internet was also a vivid example of the unexpected benefits of investments in research and development. What started as a link among DoD laboratories gradually grew to encompass a wider and wider network of computers until the Internet emerged as one of the most significant and transformative technologies both in the United States and around the world.

The overall economic climate in the 1990s remained supportive of innovation. Domestic competition, markets largely open to global economic forces, and a strong dollar all combined to keep inflation and interest rates low. The positive economic climate and the competitiveness strategy itself were both reminders of how an innovation system is embedded in a broader economic system.

Going and Growing Global

At the end of the twentieth century, the United States felt confident in its innovative prowess. Considerably greater R&D spending by the private sector complemented substantial federal funding for research. Venture capital, angel investors, and federal programs focused on small businesses gave America an edge in funding start-up firms. The United States continued to produce entrepreneurs who were eager to pursue the challenges and risks of turning new science and new technologies to practical and profitable use.

But beneath the continued vibrancy of the national system, major changes were turning the American innovation system in a decidedly global direction. Large scale projects, particularly in the scientific fields, that demanded multinational financing or cooperation, the development of truly global corporations, and the emerging competition among nations to improve their respective innovation systems have all globalized the American innovation system.

GLOBAL SCIENCE

The sheer physical magnitude of some research facilities and the recognition of problems that are global in scope has turned science into a global enterprise. In the 1980s, the United States promoted the construction of a giant superconducting super collider as the state-of-the art infrastructure needed for making the next major discoveries in particle physics. From its inception, U.S. leaders saw this as a global project that would depend on funding from around the world. The actual decision-making, however, had a decidedly American cast. The contest over the site location was fierce but limited to several U.S. states. Only after Texas was selected did the U.S. seek global financial support. However, the industrial world did not respond and the U.S. Congress eventually voted to stop funding the project.

The fate of fusion research has taken a very different path. Seven powers—China, the European Union, India, Japan, South Korea, Russia, and the United States—committed to funding the International Thermonuclear Experimental Reactor (ITER). Competition for the ITER site was conducted at an international level, unlike that for the superconducting super collider, with the ultimate choice of location eventually going to France in 2005. Fusion may or may not be the future of energy, but securing international agreement on the project and opening the site competition to all participants has laid the groundwork for future funding of mega-research facilities for programs with global relevance.

Energy is not the only challenge for global scientific cooperation. The reality that new diseases are capable of spreading quickly around the globe also presents an urgent and challenging problem, particularly as the pace of globalization has increased. The rapid spread of diseases around the globe has a long history: one need only look back to the panic that spread throughout medieval Europe during the bubonic and pneumonic plagues; the devastating impact of Old World diseases such as smallpox on New World populations; or the worldwide impact of the 1918 flu epidemic for examples of how disease can spread from one part of the globe to another. In the late twentieth and early twenty-first centuries, human exploration of previously isolated areas brought humanity into contact with a range of new diseases, such as HIV/AIDS, even as old sicknesses once rendered almost obsolete, such as tuberculosis, have become both more virulent and increasingly resistant to currently available medicines. A number of other diseases, such as avian influenza, have crossed the man/animal species barrier.

There are three differences between the twenty-first century and previous centuries when it comes to global health issues. First, the number of new diseases has multiplied. Second, modern transportation has dramatically increased the potential for spreading disease; all countries are now just a plane ride away from exposure to any given disease. In some instances, diseases are carried from place to place by migrating animals, as is the case with the latest version of avian flu, where wild birds provide the disease with wings. However, it is the third difference that will affect the course of innovation in the United States and around the world. The emergence of a multi-country response to the Severe Acute Respiratory Syndrome (SARS) outbreak in Asia in the early 2000s highlighted the extent to which medical research has become internationalized. The global impact of diseases will increasingly demand not only a system of global disease monitoring, but also multinational searches for cures. These global efforts demand that both the costs and the benefits of research be shared internationally.

The absence of cures for many tropical diseases and the high cost of drugs currently available to fight

HIV/AIDS and other truly global diseases has led the policy world to search for alternatives to the current reliance on patents as the principal incentive for commercial research in the pharmaceutical field. Governments, foundations, and private businesses are now turning to publicly funded laboratories, guaranteed purchase agreements, or the use of financial prizes to stimulate commercial pharmaceutical research.

THE GLOBAL CORPORATION

Over the last decade, corporations with an international presence have undergone a significant transition, committing more resources to global production and shifting to business strategies that are increasingly global in scope. American corporations are responding to changes in the global economy marked by a massive shift from centrally planned, largely autarkic economies to significantly greater reliance on domestic and international markets.[30]

The collapse of the Soviet Union, the Deng Xiao Ping reforms in China, and the 1991 currency crisis in India added nearly three billion new individuals to the global economy. Each new competitor state had a tradition of emphasizing education and a surplus of well-trained and underutilized scientists and engineers. Led by China, these new actors in the international economy are investing in attracting, retaining, and educating scientific talent.

In the 1980s, domestic competition, international rivals, and the promise of overseas markets led to the transfer of significant portions of U.S. manufacturing overseas. The opening of China's economy sharply accelerated that trend. The spread of broadband capacity and the emergence of a digital economy created additional challenges and new opportunities: anything that could be put into digital form could be analyzed anywhere in the world, given the right mix of modern infrastructure and human resources.

Several countries had the human talent needed to take advantage of this new situation, with India having the added advantage of widespread use of the English language. What started with a movement of customer service call-centers overseas has expanded to encompass legal research, radiology, and, more recently, cutting-edge computer chip design.

The shift in the loci of manufacturing, the development of the digital economy, and the increasing availability of a low-cost but well-educated workforce overseas have led global companies to build more of their R&D facilities in China and India, whose markets are developing rapidly. Companies are drawn to these countries by the need to be close to key manufacturers, the desire to be closer to newly prosperous customers, and the advantages offered by a growing pool of world-class and relatively inexpensive human resources.

Leading private research universities are beginning to follow the trend set by global corporations. Ivy League presidents are articulating a vision of their universities as global rather than American institutions. They intend to attract the best talent, educate future leaders from around the world, and prepare their graduates to be leaders in the global economy. Public universities, influenced by their private university peers, will feel similar pressures as they compete for students and are encouraged to support state and national economies that are increasingly linked to global commerce.

COMPETITORS SEEK TO ADOPT THE U.S. INNOVATION SYSTEM

The U.S. innovation system will also be transformed by the determination of both its old and newly emerging rivals to capture some of what they see as the American innovation magic. European and Japanese universities and firms are now competing for the scientific and engineering talent that has long flowed to the United States. Universities, national laboratories, and companies in the United States will need to respond. Venture capital firms that were once focused on supporting American companies are now invited to fund projects everywhere in the world. According to press reports and comments by venture capitalists, one question routinely asked of prospective U.S. start-ups is how the fledgling companies will take advantage of high-quality, low-cost opportunities in China and India.

Innovation: The Importance of American Culture, Values, and Enduring Goals

The U.S. innovation system is defined and sustained by an American culture that values risk, celebrates achievement, and emphasizes equality of opportunity. From Alexis de Tocqueville[31] to Seymour Martin Lipsit,[32] leading observers have remarked on the set of American characteristics encompassed by the phrase "American exceptionalism." America was created with an emphasis on individual rights, a suspicion of a strong state authority, and without a hereditary class system.[33]

A CULTURE OF SELF-RELIANCE

The American emphasis on the individual and on individual responsibility is evident in the country's response to economic hard times. In the 1930s, the Great Depression rippled around the world with a devastating effect, leading the Soviet Union to emphasize full economic autarky, driving Europeans to embrace fascism or communism, and causing other parts of the world to accept dictatorship in order to avoid what seemed to be inevitable economic anarchy.[34] There were also strong but largely peaceful currents of political discontent in the United States. For instance, the Townsend Clubs of the 1930s advocated the implementation of federal grants that had to be spent month-by-month, and Huey Long's Share the Wealth philosophy developed a national reach. However, Americans did not adopt a radical ideology or stage a military coup. Instead, they created the social security system. Even in the midst of an economic calamity that modern scholarship attributes to disastrous policy errors and major systemic flaws, Americans generally held themselves responsible for the economic crisis and searched for solutions both in cooperation with and independently of the government.

This same sense of self-reliance was again demonstrated in 1981–82, when the United States experienced its worst economic downturn since the Great Depression. In some industrial states, unemployment reached 14 percent or higher, but there was no explosion of murder in the streets, no bankers were hanged, and no politicians were shot. Instead, people from the industrial heartland got in their cars and drove south to Texas to look for work in a healthier part of the economy.

MOBILITY AND THE FRONTIER IN AMERICAN THOUGHT

Although historian Frederick Jackson Turner argued that the American frontier closed by the late 1800s as an expanding American population occupied the last open lands, the frontier remains a powerful symbol of new opportunities for Americans today. President John F. Kennedy (1961-63) described his new administration as the New Frontier. Vannevar Bush, President Truman's science advisor, titled his report on the need for a post-World War II emphasis on research, "Science: The Endless Frontier."

Like the frontier, the cowboy, a nineteenth century American icon, remains a powerful symbol of Americans' individual reliance, their willingness to take risks, and their desire to conquer new frontiers. Like the cowboys, when life did not work out in one place, Americans 'saddled-up' and tried to make it in the next town. Americans driven to the highways in search of employment far away from their homes by economic hard times were as often as not also on the move to seek education, opportunities, or a fresh start.

The ready mobility of Americans made the country's economy more flexible and resilient, and allowed innovative talent to flow from the four corners of the country to research universities or to areas with emerging industries in need of "cowboys" looking for opportunity and willing to take risks. American entrepreneurs believe that real failure is giving up on their dream and not trying again. It is not unusual to hear that a Silicon Valley inventor-entrepreneur only became a millionaire on the seventh try, not the first.

THE PURSUIT OF HAPPINESS

The founding documents of the American Republic emphasize the right to life, liberty, and the pursuit of happiness. For many Americans, these promises are fulfilled during their individual quest for new inventions and new enterprises. The pursuit of happiness is entangled with the drive for achievement and mixed with aspirations for a better life. De Tocqueville, on his celebrated tour of America, saw a prosperous nation that was nevertheless filled with a restive discontent that more had not yet been achieved. While the drive for achievement can also fuel avarice, as corporate scandals such as the Enron case illustrate, it also fuels the imagination of a Thomas Edison or the Apollo team that sent a handful of Americans to the moon and brought them safely home again.

NEITHER LORDS NOR LADIES

America was created without a hereditary class structure and still celebrates the rise of the successful from humble circumstances. Even today, politicians find it an advantage to trace their roots to the same kind of log-cabin upbringing experienced by fabled President Abraham Lincoln. When Senator Sam Ervin of North Carolina presided over the Watergate hearings that led to the resignation of President Nixon in the early 1970s, he downplayed his Harvard education and stressed his identity as a 'country lawyer.' At a senate hearing during President George W. Bush's first term, former senate majority leader Robert C. Byrd and then-Treasury Secretary Paul O'Neil sparred openly not over who had the most distinguished background, but over who had risen from the humblest circumstances. The half-truth, half-myth that anyone can do anything in America has fueled greatness in a host of fields, as well as myriad innovations in science and technology.

THE LEMONADE STAND

Driving through American neighborhoods in the late spring or early summer, one frequently encounters young children standing behind a makeshift stand selling cups of lemonade for a small sum. Parents (who probably made the lemonade) look on with pride and neighbors come by to purchase a cup and to praise the youngsters' budding entrepreneurial skills.

America is rare among the industrial powers in that it weaves business lessons into early childhood. Parents are not alone in encouraging business sense in their young children. Junior Achievement, a non-profit organization, developed a business curriculum that volunteers bring into elementary school classrooms. The Kansas City-based Kauffman Foundation encourages early childhood business experience by supporting education in math, science, and technology. The Kaufmann Foundation is working to create a model for the preparation of "the next generation of entrepreneurs and workers needed in America's global knowledge economy."[35]

The independent cast of mind encouraged by an emphasis on entrepreneurship may even provide a creative spark to the future scientist. Entrepreneurial instincts certainly contribute to the link in the American innovation chain that looks to inventors to turn ideas into commercial products. This "make-it-a-business" urge was an important part of the 1980s and 1990s Silicon Valley model: large companies nurtured innovative scientific and engineering talents, who frequently left to start a small business of their own, only to find that a successful venture required the active involvement of a larger company with greater manufacturing and marketing skills.

GIVE ME YOUR EDUCATED ENGINEERS, YEARNING FOR OPPORTUNITY

This phrase is, of course, a take-off of the famous words carved into the Statue of Liberty and into every American's mind: "Give me your poor, your huddled masses yearning to breathe free." This rephrasing highlights the contributions made by immigrants and immigration to the American innovation system. The list of American Nobel Prize winners is full of scientists who immigrated to the United States. Today, as much as a third of the scientific and engineering workforce in the United States is foreign-born, and studies of Silicon Valley have found that, over the past twenty years, roughly a third of new technology businesses were started by Chinese or Indian immigrants.

What accounts for America's success in attracting so many talented immigrants? Factors include the push of political turmoil and war in Europe in the mid-twentieth century, as well as limited opportunities for research and scientific careers. The pull of America's prosperity and investment opportunities and the country's strong commitment to research are also contributing factors, as is the unique element that scholars often refer to as America's "civic religion." This "religion" is itself a mix of national ideals—freedom of speech and religion, equality of opportunity, self reliance, care for the community, and a commitment to hard work and democracy. This American creed is coupled with an evolving culture that emphasizes fair play and civic decency.

As a consequence of its immigration tradition, America does not define itself in primarily ethnic terms. The reigning ideals remain equality of opportunity and being judged as an individual. America is still evolving toward the high standards of its civic religion—discrimination based on ethnicity, gender, and race still occurs, but it is gradually giving way as the result of decades of struggles for equality and recognition inspired by the country's founding creed.[36]

INNOVATION AND THE AMERICAN DREAM

For the majority of twenty-first century Americans, the pressure to achieve individual success has been a powerful element in their drive to discover and create. The American Dream is built around individual success—owning one's own home, sending the children to college, going beyond what one's parents were able to achieve. The drive to move ever-upward is multidimensional and includes a process of discovery, innovation, and, often, starting one's own business, where individual ideas can be turned into competitive products and services.

In addition to the American Dream so often linked to individual achievement, dreams for America as a nation and for America's special place in the world have also pushed the country forward. In describing America as a "City on a Hill," President Ronald Reagan was invoking an image penned by John Winthrop in the early seventeenth century as he crossed the sea from England to the colonies that would become America. Like Winthrop, Reagan believed that America has a special mission to be an inspiration to the world through the force of its example. Early in the twentieth century, President Woodrow Wilson led America into World War I and a more active engagement with world affairs—not for territory or resources but to spread the gospel and practice of democracy. Both of these visions for America's place in the world influence present day national policy.

How do the individual American Dream and the dreams for America as a nation link to innovation? The individual dream drives the engineer, the scientist, and the entrepreneur. The expectation of American leadership in the world, including in innovation, influences policy makers and the public at large. The ability to innovate provides an important underpinning for both the individual American Dream and the dreams for America—producing growth, better health, and an improved environment at home, and contributing to the national strength needed for effective engagement around the world.

Innovation—Growing Through History, Building Institutions, Sustained by American Values

The United States can no longer take its leadership in innovation for granted. Temporarily blinded by its post-Soviet status as the sole military superpower, the United States is only now focusing on the determination of both old and new competitors to develop their own innovative capacities. Gradually awakening to this challenge, the United States must refocus its entire innovation system, from its schools, to the funding of research and development, to the maintenance of a diversified manufacturing base.

The American innovation system has many strengths, including world-class universities, an extensive network of national laboratories, and significant public and private spending on research and development, which can help it stay competitive in the twenty-first century. In the future, as in the past, the United States can build on flexible institutions, a mobile population, and a culture that supports exploration and risk-taking. The world's best and brightest can still find ample opportunity in a United States that generally makes immigrants feel quickly at home.

But the system has long-standing weaknesses as well. Despite periodic cries for reform, the United States' K-12 education system continues to lag behind the best systems in Europe and Asia. Although the rise of Japan in the 1980s forced many public and private leaders to think of U.S. innovation in terms of a system, that focus faded in the bright glow of the prosperity of the 1990s. In some fields, the United States remains dependent on defense spending and a handful of other national missions to drive innovation. Despite a long history of public sector involvement, an almost ideological aversion to a public (i.e. government) role in the economy can slow and limit the national response to emerging challenges.

In the coming decades, the United States and its innovation system face a series of new challenges, both domestically and globally. China, India, and other emerging-market countries are luring more of their immigrant talent back home and are attracting the R&D facilities of leading American companies. Much of the world has diagnosed the strengths of the American innovation system and is attempting to emulate them, in part by competing for the human resources that flowed so effortlessly to American shores in earlier decades. The U.S. manufacturing base that supported so much private sector research is being significantly eroded as U.S. firms respond to the pressures of an overvalued dollar and the lure of high-quality, low-cost labor overseas. Major domestic concerns, among them insufficient healthcare and social welfare programs, seriously threaten to overwhelm government funding for innovation and R&D.

However, the growth of research capacity around the world creates enormous opportunities for U.S.-based researchers and research institutions. Basic scientific discoveries in overseas laboratories will enrich the possibilities for innovation everywhere. The same is true of new technologies. The American-invented Internet is an example of a transformative technology that is boosting productivity around the world.

As the flow of international talent to the United States slows, America must concentrate on improving the pool of domestic talent by providing the education necessary to compete in scientific and engineering disciplines. A larger potential supply of talent must be matched with the research funds and life-long opportunities that make scientific or engineering careers both possible and attractive. American laboratories and American companies need to become both more adept at looking around the world for innovations and at putting them to use in the creation of new products, more efficient processes, and better jobs in the United States.

With regard to America's future as a leader in innovation, students of the American innovation system might paraphrase the advice that Shakespeare wrote for Brutus some five hundred years ago: "your fate, dear America, lies not in the stars but in yourself."

02

CHAPTER TWO
INNOVATION IN GERMANY

INNOVATION IN GERMANY

AXEL WERWATZ

In the 1980s, Americans considered Germany a threat to the United States' leadership in technology and innovation. In a recent benchmarking of national innovative capacity, however, Germany only achieved a middle ranking among leading industrial countries, with the United States coming out on top. Why did Germany lose ground in recent decades? Is the "German way of innovation," if there is one, on the decline, unable to adjust to a rapidly changing global environment?

This essay uses the aforementioned benchmarking study, prepared by the German Institute for Economic Research in Berlin, as its point of departure for answering these questions. The study provides a comprehensive picture of the current condition of the German innovation system, pointing to its specific features, its particular strengths, and its greatest weaknesses. It also provides the proper point of reference for a broad look at the historical path leading to today's German innovation system, which in turn provides greater understanding of the current condition of innovation in Germany.

Germany's Current Innovative Capacity

When Germany, as well as most of its highly developed European neighbors, looks for sources of future growth and prosperity, innovation takes center stage. Innovation is supposed to be the driving force that will turn the European Union into "the most competitive and dynamic knowledge-driven economy in the world"[38] by 2010. After several years of sluggish growth and the emergence of new competitors in Europe and Asia, innovation has become a particularly urgent matter in Germany. As a result, the current government is seeking to combine all its strategic measures for strengthening innovation into a single action plan, the "High Tech Strategy Germany."

Reflecting the growing interest of policy makers and the general public in innovation, in 2005, for the first time, the Berlin based German Institute for Economic Research (DIW Berlin)[39] prepared a composite indicator of national innovative capacity for Germany and twelve other leading industrial countries. As Figure 1 shows, the foundation of the composite "Innovation Indicator for Germany" is a multitude of individual indicators for various elements that contribute to innovation. The composite indicator is developed incrementally from one stage to the next, from the basics upward via several intermediate levels. The top level represents the overall score of national innovative capacity.

In this bottom-up structure, the final two levels are particularly important. In the next-to-last level, the system indicator and actors indicator are formed from underlying composite indicators. In the top level, the overall composite indicator is formed by combining the composite indicators for the innovation system and the innovation actors. The innovation system indicator is comprised of indicators for seven component areas: education, research and development, financing of innovations, networking among innovation actors, implementation of newly developed innovations, regulations promoting innovation and competition, and innovation-friendly demand. Together, these seven indicators constitute the framework conditions that form the national innovation system. The system is molded and animated by the key innovation actors: companies, the state, and citizens. The capacity of these actors to promote innovation is measured by the three corresponding composite indicators feeding into the innovation actors branch of Figure 1.

Using this multi-level construction, the contributions that individual areas of the innovation system make towards the total result and the role key actors play in the total result can be identified. In this manner, not only can an overall score of national innovative capacity be computed (Figure 2), but an "innovation profile" for Germany (Figure 3) can be derived that lays out the country's strengths and weaknesses relative to those of the twelve other countries to which it is compared.

Out of a group of thirteen leading industrial countries (Figure 2), Germany's innovative capacity was given an average ranking that placed it in the middle of the field. The United States was ranked first, followed by three Scandinavian countries and Japan. In and of itself, a sixth place innovation indicator is not yet cause for concern. However, in comparison to the scores for innovative capacity obtained by the United States (7, on a scale of 1-7), Finland (6.01), and Sweden (5.83), Germany's relatively low score of 4.66 indicates that the country suffers from considerable disadvantages in innovative capacity.

Germany's 'innovation profile'—its particular advantages and disadvantages in the area of innovation—is illustrated in the tiers of ten sub-indicators given in Figure 3. The first conclusion to be drawn from this profile is that Germany does not truly stand out in any particular area, either positively or negatively. The overall impression of an average position thus largely carries over to the separate components of the innovation system and the key innovative actors.

Yet, several strengths and weaknesses can be identified from Figure 3. Particular advantages exist on the systems-side in networking and the implementation of innovations, in the sense of companies enjoying success with research and development intensive products on international markets. Serious disadvantages were identified in the education sector and with respect to the financing of innovative projects. Surprisingly, Germany's worst ranking was on the actors side, in the innovation-relevant behavioral patterns and attitudes of the population. The current state of Germany's innovation system can be char-

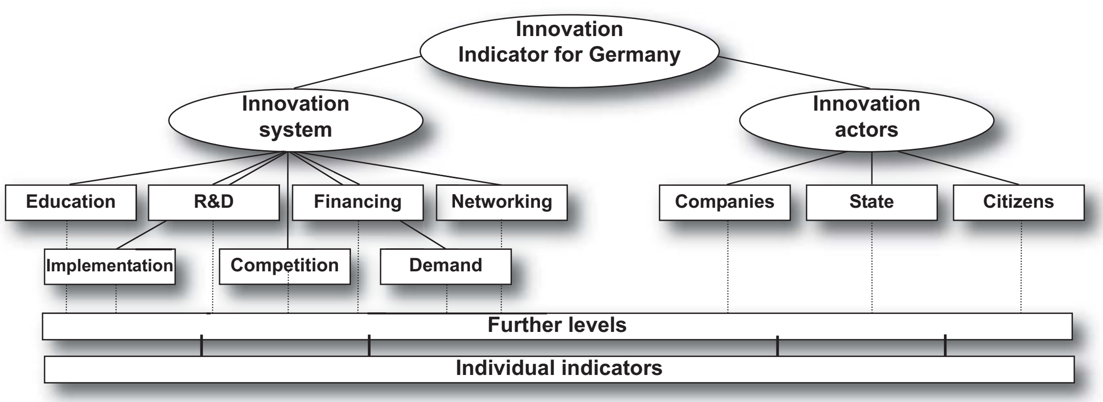

Figure One: Structure of the Innovation Indicator for Germany

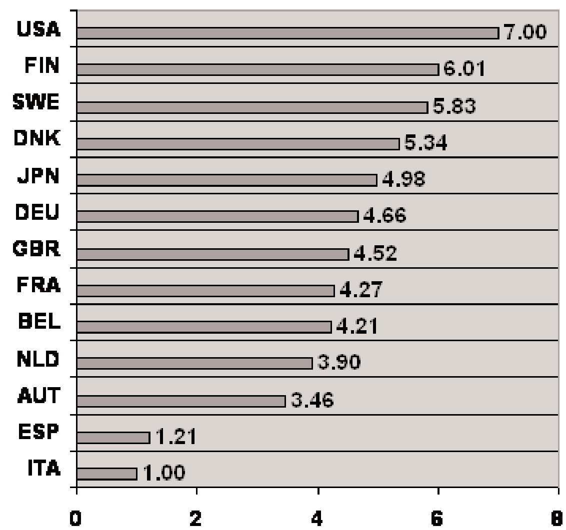

Figure Two: Scores of Countries for the Overall Indicator—seven is highest possible score

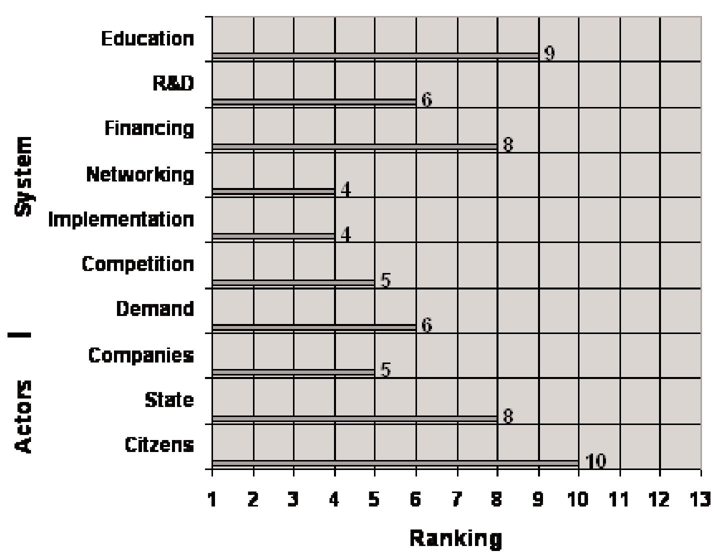

Figure Three: Germany's Innovation Profile acterized through a closer look at these areas of particular strength and weakness.

Germany's Strengths

IMPLEMENTATION

Germany's particular strength in the implementation of innovations may be surprising to some. A popular (mis)conception is that while Germany is strong in basic research, the findings resulting from such research are "rotting in the closet," i.e. they are not implemented and brought to the market place.

The tree diagram in Figure 4 shows how the composite indicator for the 'implementation of innovations' was constructed and helps to explain Germany's strong position in this area, which rests on two pillars: the necessary infrastructure in terms of both physical and information and communication technologies, and actual productive activity. The indicator for the latter is itself composed of several branches: medium- and high-tech manufacturing, knowledge-intensive services, knowledge-intensive production, and high-tech start-up activity.

Deconstructing Germany's relatively high score on implementation into its constituent components reveals that this score is based on excellent infrastructure and the extraordinary market success enjoyed by Germany's medium-tech[40] manufacturing industries as the result of innovative products and processes. Germany's strength in R&D intensive industries such as machinery, automobiles, and chemicals makes the country the 'world champion of exports.' Nevertheless, this behind-the-scenes glance at the Implementation sub-indicator also shows that Germany's record is rather poor in future-oriented, cutting-edge[41] technologies with very high R&D intensity, such as information and communication technologies (ICT), including microcomputers, semiconductors, telecommunications, biotechnology, and aerospace. Indeed, Germany has failed to achieve technological leadership in any of the high-tech industries that emerged after World War II. This is also reflected in Germany's low score for support of start-up business ventures. Germany scores high in implementation on the strength of its infrastructure and medium-tech industries, which overcompensate for its weakness in high-tech industries and the establishment of new innovative companies.

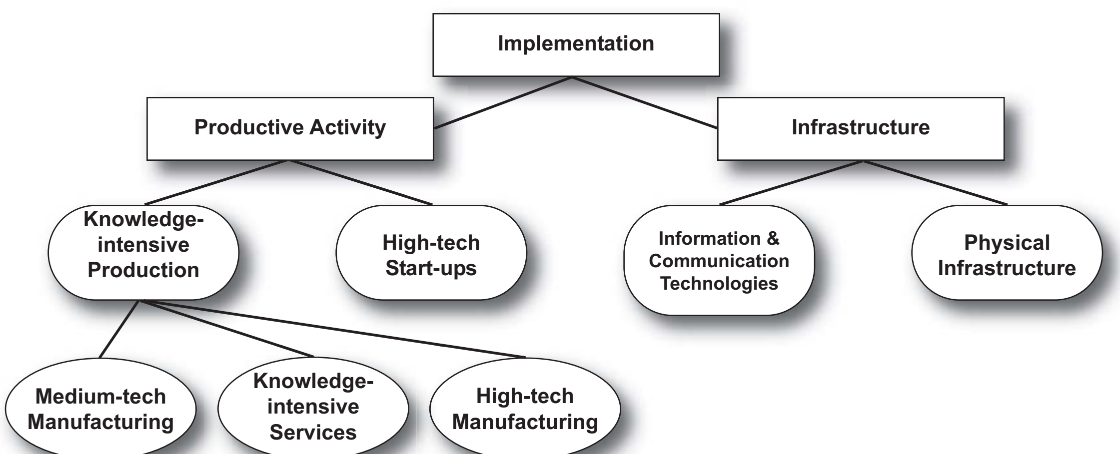

Figure Four: Composition of the Implementation Indicator

NETWORKING

According to Figure 3, another strong point of the German innovation system is networking, particularly among enterprises. The composite indicator of networking—a difficult to qualify but nevertheless important indicator—encompasses survey-based measures on the condition and extent of cluster development and collaboration, the intensity of university-industry research collaborations, and the quantity and quality of local suppliers. Germany receives especially high marks regarding the latter. Larger German enterprises successfully operating in world markets for medium-tech goods can tap into a local knowledge base, composed primarily of their *Zulieferer* (local suppliers).

Germany's Weaknesses

Once a front-runner in education and a role model in this area for other countries, the German *Bildungssystem* (education system) has suffered in recent years from underlying deficiencies that became fully apparent in 2001 with the so-called "PISA-Shock." German students' poor showing in the Program on International Student Assessment (PISA)[42] study of 15-year olds' academic achievement propelled the condition of the German education system into the national spotlight. This shock, which still reverberates throughout Germany in 2006, has led to an almost unanimous consensus that education is a major problem and has also resulted in a variety of opinions on how to resolve the issue.

While receiving less attention from the media and the general public than elementary and secondary schools, German colleges and universities fail to produce the number of tertiary graduates seen in countries such as the United States. Part of the problem is Germany's rigid secondary school system, which provides an insufficient supply of entrants in the first place. However, the country's universities, most of which are publicly funded, have neither the autonomy nor the incentives[43] required to illicit a positive response to increased demand for university-trained labor.[44] At the same time, there does not appear to be a strong focus on excellence, as German universities fail to score high in emerging international rankings on university research performance. The research university, once an admired institutional innovation of the German system, must therefore now be considered part of its problems. In short, many factors, such as input (students) and the quantity and quality of output (graduates, research, etc.), indicate that the German educational system is severely flawed and fails to provide the innovation process with its most important resource: a sufficient supply of highly qualified human capital.

The supply of human capital, however, is not the only clearly visible weakness of the German innovation system; it also suffers from a serious shortage of risk capital, particularly for high-tech start-up companies. A well-functioning private equity industry, necessary to provide the venture capital needed for vibrant start-up activity, has not emerged in Germany.

A puzzling weak point of Germany's innovative capacity can be found on the actor side. While companies rank fifth on the German Innovation Profile (Figure 3), the evaluation of behavior promoting innovations and the attitude of the population (classified as "citizens" in Figure 3) is clearly less favorable, falling in tenth place. This finding is caused by various factors: compared internationally, the German population is relatively risk-averse, the participation of women in innovation processes is low, and scientific knowledge and the interest exhibited in science and technology are below average.

The History of Innovation in Germany

A look at the history of the German innovation system is instructive for understanding Germany's current capacity for innovation and for further characterizing the German approach to innovation. Even in this perceived stronghold of orderliness—stereotypically, Germans are thought of as punctual, efficient, and disciplined—the German innovation system did not take its current shape as the result of a careful planning process. Quite to the contrary, it developed in a hurry, particularly during the second half of the nineteenth century. The rapid rise of the German economy occurred after years of stagnation following the Thirty Years War (1618-1648), which had wiped out a third of Germany's population at the time and left behind a deeply fragmented country. The consequence of this fragmentation was not fruitful, dynamic competition between the many independent territories that occupied what was to become the Deutsches Reich. Rather, compared to its European neighbors, Germany was a late bloomer economically and industrially.

THE RISE OF THE GERMAN UNIVERSITY

Some of the seeds responsible for finally making Germany bloom economically were planted at universities such as those in Göttingen (founded in 1742, in what was then the Kingdom of Hannover) and in Berlin (founded in 1809 in what was then Prussia). These were among the first instances of universities being transformed from mere institutions of higher learning to centers of cutting-edge research. Faculty for these institutions was selected from a pool of scholars who had built their reputations through their publications. This focus on publication served to create research universities that eventually also attracted many students; attendance numbers increased from 14,000 in 1870 to almost 60,000 in 1914. German universities became places of world-class scholarship and research, particularly in the natural sciences.

However, laboratory research and engineering were not initially part of the university system, as they were not held in high esteem by a culture shaped by the idealist views of Wilhelm von Humboldt, the founder of what is now Humboldt University in Berlin (originally named Berliner Universität), and his peers. Polytechnical schools for training engineers and technicians were first established in Prussia in 1820. These schools, which were soon established in many other parts of Germany, rose in standing along with the engineering profession and eventually, in 1870, were given the status of *Technische Hochschulen*, which was equivalent to the status held by universities. Today, several of these institutions, such as the *Reinisch-Westfälische Technische Hochschule Aachen* (RWTH), the *Technische Universität Darmstadt*, and the *Technische Universität München*, are among the highest ranked universities in Germany and also enjoy good standing internationally.

The rise of German universities and institutions of higher learning was complemented by a high rate of primary school enrollment and the successful adaptation of the apprenticeship system from a crafts-based economy to the needs of an industry-based economy. In the second half of the nineteenth century, Germany's skill base was impressive for both its breadth and its excellence.[45]

THE RISE OF GERMAN INDUSTRY

Success in science-based industry followed on the heels of Germany's achievements in higher education. Building on the strength of the country's university research, German pharmaceutical and chemical firms began to gain technical and commercial leadership in world markets in the second half of the nineteenth century. During the 1860s, future industrial giants like Bayer, BASF, and Hoechst were founded. These companies were among the first to establish corporate research departments.

The electrotechnology industry, which featured such heavyweights as AEG and Siemens, also had great success in the late nineteenth century, inspiring a response in academe; the first professorial chair for electrical engineering was established in 1882 at the Darmstadt University of Technology. Capitalizing on the new opportunities brought about by electric power, the German machinery construction industry began its eventual rise to the top of the world ranks.

While the German automobile industry did not really blossom before World War II—despite a series of early technical inventions associated with names such as Otto, Diesel, and Daimler—it was nevertheless possible for Otto Keck to conclude in a 1993 article about industry in early twentieth century Germany that "in most industries that today are net exporters Germany performed well on the world market in 1913."[46] The period of rapid growth in industrial output and industrial exports from the middle of the nineteenth century to 1913 brought Germany's per capita income almost equal to that of Great Britain.

During this period, several institutions were created to facilitate the flow of research findings to industry and the flow of industry money to research funds.

Specialized research institutes in applied areas were founded to complement the more academic research carried out at universities, *Technische Hochschulen*, and the academies of science. Some of these specialized research institutes were funded with industry donations collected by the Kaiser Wilhelm Society, founded in 1913, which became the Max Planck Society after World War II.

Today, the Max Planck Society for the Advancement of Science is an independent German non-profit research organization funded by the federal and state governments. It operates eighty institutes in Germany, each tasked with conducting basic research in the natural sciences, the social sciences, and the humanities.

CREATIVITY IN THE MIDST OF POLITICAL DISASTER

The breathtaking pace of development in German science, technology, and industry was not complemented by political progress. Democratic forces had lobbied for political union of Germany's numerous individual provinces since the early nineteenth century. However, it was the principles of power and Prussian military strength that led Germany to unity, not the principles of freedom and democracy. Some have speculated that this lack of a spirit of democracy eventually resulted in the catastrophes of two World Wars.

The crises that followed World War I—among them hyperinflation in 1923 and the stock market crash in 1929—not only aided the rise of the Nazis, but led also to the creation of new institutions that have left their mark on today's German innovation system. The German Science Foundation (*Deutsche Forschungsgemeinschaft*) grew out of the Emergency Association of German Science (*Notgemeinschaft der Deutschen Wissenschaft*), founded in 1920 to relieve the negative effects of inflation and unemployment by providing research grants to individual scientists. The associated Donors' Union (*Stifterverband der Notgemeinschaft*), established to collect donations from industry, is the predecessor of today's Donor's Union for German Science (*Stifterverband für die Deutsche Wissenschaft*).

The economic turbulence of the 1920s sparked "extraordinary creativity and readiness to experiment"[47] and, despite many difficulties, supported increases in some of the key measures of innovative capacity, including public R&D spending and the distribution of patents.[48] Even exports rebounded from the negative effects of World War I. These successes were, however, short-lived due to the political turmoil caused by the collapse of the Weimar Republic in 1933 and the rise to power of the National Socialist Party.

The many disasters inflicted by Nazi Germany included severe damage to Germany's research universities and higher education system. Enrollment in higher education was drastically reduced under the Nazi regime and some of Germany's best scholars were removed from their positions and forced to emigrate. The effects of Nazi rule on industry, however, may have been less severe. According to Keck, the planning machinery of the Nazis "did not radically change the innovation system" as it "was put on top of existing industrial structures."[49]

MIRACULOUS RECOVERY

How big a role the Hitler government's relatively minor interference with the German industrial structure played in the "miraculous" recovery of the (West) German economy after World War II is difficult to determine. At any rate, it contributed to the continuity that characterized the innovation system's transition into the post-war period. As Keck notes: "In all these changes, the basic components of the innovation system were reconstructed: the firms and their laboratories, the schools, the universities and *Technische Hochschulen*, the Kaiser Wilhelm Society, the *Deutsche Forschungsgemeinschaft*, government research institutes, and business and technical associations."[50] Public expenditure on science and technology, as a share of the total public budget, was increased dramatically after World War II[51] and was shifted towards R&D rather than university education.

The federal government gradually assumed an increasing role in the process of stepping up government support for science and technology, although the individual German states had initially provided the lions' share of funding.[52] A visible sign of the federal government's increasing role was the establishment of the Federal Ministry of Scientific Research in 1962,[53] which was renamed the Federal Ministry of Education and Science in 1969 after the education and research responsibilities of the federal government were increased. A greater emphasis on R&D led to the creation of the Federal Ministry of Research and Technology in 1972. These two ministries were merged in 1994 under the title "Federal Ministry of Education and Research." In 2005, significant portions of this ministry were shifted to the Federal Ministry of Economics, which, fittingly, added "Technology" to its name.

These frequent changes in the name and organizational makeup of the ministry responsible for science and technology policy point to the numerous tensions and questions surrounding the respective roles of the federal and state governments in science and technology and education policies, which were further demonstrated by fights over just this issue during debates in 2006 on the reform of Germany's federal system. Neither the federal government nor any of the German states assumed the responsibility for actively managing the national innovation system. Not even Bavaria or Baden-Württemberg, Germany's leading industrial states, assumed a leadership role in championing a "competitive federalism" policy for Germany.

The postwar period also saw an ever-increasing share of total R&D expenditure being provided by private business. This contributed to an intensity of R&D in Germany, relative to GDP, which even exceeded that of the United States, at least during the 1980s, and raised fears across the Atlantic about German (in addition to Japanese) technological dominance. How much of the expansion in business R&D was brought about by increased government efforts to boost technology transfer and networking is controversial.

There is, however, a consensus that the expansion of the Institutes of the Fraunhofer Society, established in 1949, marked an important post-war institutional innovation. The Society's core funding—provided by the government—amounts to about one-third of its annual budget and is contingent upon the Institutes' ability to win research contracts. The Fraunhofer Society Institutes thus have a strong incentive for doing contract work and for serving their clients in industry and government. The Frauenhofer Society also has a strong incentive to establish (or close) Institutes on the basis of perceived demand for contract research, or a lack thereof. The Society, which has grown substantially and maintains close ties with neighboring universities, is therefore seen as a key link between universities and industry.

"WHAT BELONGS TOGETHER…": INNOVATION IN REUNIFIED GERMANY

The end of the Cold War and the reunification of Germany understandably led to new German economic priorities. The task of achieving economic unity by rebuilding the East German economy took center stage on the national agenda and continues to command a considerable amount of the country's resources.

The division of Germany into East and West during the Cold War not only resulted in a big gap in the standard of living, but also in the level of and standards for science and technology. Reunification, however, revealed that similarities between East and West nevertheless existed. Analyzing publication data from both East and West Germany, Grupp et al. found a great deal of similarity in terms of specialization. Publications by researchers from both the East and the West showed a disproportionately high degree of specialization in areas such as energy and nuclear technology, chemistry, solid-state physics, and microbiology. A similar analysis of patent portfolios also showed a close correlation between East and West Germany. Grupp et al. concluded that obviously, forty years of division were not sufficient for a differentiated development of the specialization patterns of research in both parts of Germany. To a great extent, and in the sense of path dependency, research is still based on the (common) preferences which existed prior to the division.[54]

Does former Chancellor Willy Brandt's famous reunification quote, "what belongs together is now growing together," then also apply to the field of science and technology? Grupp et al. give an affirmative answer by interpreting the results of their comparative analyses of Eastern and Western publications and patents as indications of a uniquely German approach to science and technology, a "sustainable cultural imprint," that prevailed despite dramatic political and economic changes in the post-war era.

This apparent path dependence is not confined to the realm of science and research. German industrial specialization also shows a great deal of continuity between East and West. Continuing success with the production of R&D intensive drugs, chemicals, cars, and machinery is proof of the ability of German industry to produce a continuous stream of innovations, albeit in a very stable set of areas. It is, according to Grupp, another aspect of a specific German *Innovationskultur* (innovation culture), a "specific German understanding of the opening and prosecution of technology trajectories"[55] shaped by the self-conception of German researchers, firms, and consumers.

The Road Ahead

IN THE RIGHT BUSINESS?

The continuities described above have been interpreted in very different ways. One view interprets this evidence as a clear indication of a rigid innovation system unable to adjust to new technological and economic opportunities and operating mainly in stagnating markets bound to be dominated in the twenty-first century by newly industrializing countries like China and India. An alternative view, recently expressed by Beatrice Weder Di-Mauro of the German Council of Economic Experts, is much more positive in the European context. She argues that, at first glance, markets for high-tech products appeared to be more desirable than those for medium-tech markets, offering more potential for spillovers and more potential for growth than the latter. However, from her analysis of Europe's (and Germany's) strong export performance,[56] she concludes that "so far Europe has specialized in the right markets and products,"[57] as medium-tech products incorporate many high-tech discoveries and experience a growth of worldwide demand that has expanded at the same rate as overall trade.

MARKET FORCES

While the merits of Germany's industrial specialization may be subject to debate, there is little doubt about the decline of Germany's education system and its research universities from strong pillars of the innovation system to serious weak points in the structure. There also appears to be a consensus that increasing competition in these subsystems of the larger innovation system would be highly desirable. This could be accomplished by granting more autonomy and responsibility to educational institutions, particularly to universities.

Underlying this recommendation to rely more heavily on market forces and competition is the commonly held view that the United States, by championing market forces, has achieved superior innovative and growth performance in recent years.[58] This view is particularly convincing in light of Germany's relatively weak record of fostering high-tech start-ups, an area in which the United States is strong. Highly flexible entrepreneurial start-ups are a necessary ingredient for success and leadership in the development of rapidly changing high-tech markets, but they require investors, managers, and scientists willing to bear the high risk of potential failure associated with such enterprises. At present, Germany seems to lack the right market environment necessary for supplying the incentives and rewards for making these risky ventures an attractive option.

Recommendations for greater reliance on market forces, however, may not be easily reconciled with the mixture of preferences and institutions that shape the German *Innovationskultur*. Indeed, altering only parts of this system may prove counterproductive, running the risk of failing to deliver new opportunities and rewards while impairing those aspects of the system that had operated with a modicum of success in the past. Despite their shortcomings, the interplay of the current system's components has created an endogenous comparative advantage that has served the German economy well. This comparative advantage is composed of relationship-financing, rather than market-based equity financing; less flexible labor market rules, rather than easy employee dismissal procedures; and public institutions for knowledge transfer, rather than market transactions. These elements may all add up to a German variety of capitalism that has limited opportunities for radical innovations in new technologies, but that simultaneously fostered the absorption and transformation of radical innovations into a constant stream of product and process innovations, allowing German firms to enjoy continued success on world markets.

NOTES

1 Pat Choate, *Hot Property: The Stealing of Ideas in an Age of Globalization* (New York: Alfred A. Knopf 2005): 29. As Choate put it, "…between 1793 and 1836 the U.S. government issued patents only to foreign citizens who worked in America, had alien status, or swore an oath to take citizenship."

2 Ibid., p. 41.

3 The Morrill Act became law in June of 1862 during some of the most difficult days of the American Civil War. For a brief history, see Edward Danforth Eddy, *Colleges for Our Land and Time: The Land-grant idea in American Education* (New York: Harper & Brothers, 1956): 32-41.

4 See David C. Mowery and Nathan Rosenberg, "The U.S. National Innovation System," in *National Innovation Systems: A Comparative Analysis*, ed. Richard R. Nelson (New York: Oxford University Press, 1993): 36-37.

5 Ibid., p. 32.

6 As quoted in Michael E. Porter, *The Competitive Advantage of Nations* (New York: The Free Press, 1990): 371.

7 See Alfred D. Chandler, Jr., *Shaping the Industrial Century: The Remarkable Story of the Evolution of the Modern Chemical and Pharmaceutical Industries* (Cambridge, Massachusetts: Harvard University Press,2005): 21. See also Choate, *Hot Property*,125.

8 See President George W. Bush, 2006 State of the Union Address, www.WhiteHouse.gov

9 See Mowery and Rosenberg, *U.S. National Innovation System*, 46.

10 See "Funding the Foundation: Basic Science at the Crossroads", ed. Kent Hughes, Lynn Sha, and Caroline Vazque (Washington, DC: Woodrow Wilson Center, 2006): 32.

11 See Mowery and Rosenberg, *U.S. National Innovation System*, 36.

12 See Eddy, *Colleges for Our Land and Time*.

13 Dennis K. Berman, "At Bell Labs, Hard Times Take Toll on Pure Science," Wall Street Journal, May 23, 2003.

14 John Lerner, "Venture Capital," in T*echnological Innovation & Economic Performance*, ed. Benn Steil, David G. Victor, and Richard R. Nelson, (Princeton, New Jersey: Princeton University Press,2002): 328.

15 Recent research suggests that America might have beaten the Soviets into space, but held back. See T.A. Heppenheimer, "How America Chose Not to Beat Sputnik into Space," *Invention and Technology* (Winter 2004).

16 The reaction to Sputnik actually took shape during the Eisenhower Administration. See for instance, Robert A. Divine, *The Sputnik Challenge: Eisenhower's Response to the Soviet Satellite* (New York: Oxford University Press, 1993).

17 Ibid. 100-101.

18 John A. Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter, Gerald L. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press,1992): 137. The quote is from Public Law 83-325 establishing ARPA.

19 AnnaLee Saxenian, "The Genesis of Silicon Valley," in *Silicon Landscapes*, ed. Peter Hall and Ann Markusen (Boston: George Allen & Unwin, 1985), as referenced in Ann Markusen, Peter Hall, and Amy Glasmeier, *High Tech America: The What, How, Where and Why of the Sunrise Industries* (Boston: George Allen & Unwin, 1986): 73.

20 AnnaLee Saxenian, "The Limits of Autarkey: Regional Networks and Industrial Adaptation in Silicon Valley and Route 128," HUD Roudntable on Regionalism, December 8-9, 1994. See also Saxenian, *Regional Advantage: Culture and competition in Silicon Valley and Route 128* (Cambridge, Massachusetts: Harvard University Press, 1994).

21 Charles W. Wessner, ed., *Government-Industry Partnerships for the Development of New Technologies* (Washington, DC: National Academies Press, 2003). Pages 102 to 103 provided succinct summaries of a number of steps taken between 1980 and 1992 to speed the transfer of innovations into competitive products and processes.

22 The National Cooperative Research Act of 1984.

23 The Federal Technology Transfer Act of 1986 amended the 1980 Stevenson-Wydler Act.

24 The National Competitiveness Technology Transfer Act of 1989.

25 For more background on the Advanced Technology Program see Christopher T. Hill, "The Advanced Technology Program: Opportunities for Enhancement," in *Investing in Innovation: Creating a Research and Innovation Policy that Works*, ed. Lewis M. Branscomb and James H. Keller, (Cambridge, Massachusetts: The MIT Press,1998): 143-173. Also see Charles W. Wessner, ed., *The Advanced Technology Program: Challenges and Opportunities* (Washington, DC: National Academy Press, 1999).

26 For an evaluation of the credit, see U.S. Congress, Office of Technology Assessment, *The Effectiveness of the Research and Experimentation Tax Credits*, Washington, DC, September 20, 1995 and U.S. GAO, *Tax Policy and Administration: Review of Studies of the Effectiveness of the Research Tax Credit*, GAO/CGD-96-43, Washington, DC, May 1996.

27 For personal testimony of the changes forced on Bell Labs see Narain Gehani, *Bell Labs: Life in the Crown Jewel* (Summit, New Jersey: Silicon Press, 2003).

28 See Michael Porter's diamond that emphasizes the public role in providing key elements for growth. Porter, *Competitive Advantage*, 71-73.

29 See Laboratories of Democracy and the example of Arkansas.

30 Daniel Yergin and Joseph Stanislaw, *Commanding Heights: The Battle Between Government and the Marketplace that is Remaking the Modern World* (New York: Simon & Schuster, 1998).

31 Alexis de Tocqueville, *Democracy in America*, trans. George Lawrence, ed. J.P. Mayer (Garden City, New York: Doubleday & Company, 1969).

32 Seymour Martin Lipset, *American Exceptionalism: a Double-Edged Sword* (New York: W.W. Norton & Company, 1996).

33 The great exception to the American rule has been the treatment of African Americans, who for three centuries were either enslaved or systematically judged not by their character, but by the color of their skin.

34 Karl Polanyi, *The Great Transformation: The Political and Economic Origins of Our Time* (New York: Rinehart & Co., 1944).

35 The Kauffman Foundation, "About the Foundation," http://www.kauffman.org/foundation.cfm (accessed 11 September 2006).

36 Lipset, *American Exceptionalism*, see especially chapter 4.

37 See http://www.innovationsindikator.de/. A brief English version of the study is published as Heike Belitz and Axel Werwatz, "Capacity for Innovation: Among Leading Industrial Countries, Germany Only Manages a Middle Rank," DIW Berlin Weekly Report, January 2006, 1-10.

38 Presidency Conclusions from the Lisbon European Council, March 23-24, 2000, http://ue.eu.int/ueDocs/cms_Data/docs/pressData/en/ec/00100-r1.en0.htm

39 DIW Berlin is Germany's largest non-profit economic research institute and engages both in scholarly research and independent and timely policy advice. Its seven research departments cover a wide range of today's most imminent topics such as innovation, reform of public finance in an ageing population or the economics of climate change.

40 "Medium-technology goods" are goods requiring intense research prior to marketing and for which expenditures for research and development make up a percentage of the turnover greater than 3.5 percent. Cf. in this context the definition provided in the reports on technology performance published regularly by the *Bundesministerium für Bildung und Forschung* (German Federal Ministry of Education and Science).

41 Goods are counted as "goods of cutting edge technology" if the expenditures for their research and development make up a percentage of the turnover greater than 8.5 percent.

42 PISA's (http://www.pisa.oecd.org) world-wide testing of fifteen-year old schoolchildren's scholastic performance was first carried out in 2000. The tests, carried out on behalf of the OECD by an international consortium headed by the Australian Council for Educational Research (ACER) cover reading ability, as well as mathematical and scientific literacy. The scores of German students in 2000 were below the OECD-average and showed a particularly strong correlation with parents' academic achievements. In the most recent PISA results, German students scored at the OECD average, while their results still show a particularly strong correlation with their parents level of education.

43 At present, significant tuition fees are still largely absent.

44 The wide-spread introduction of Bachelors degrees as the first and primary exit channel for university graduates only took place as a reaction to external pressure exerted by the European Union's Bologna Process for harmonizing academic degrees throughout Europe.

45 Otto Keck, "The National System for Technical Innovation in Germany", in *National Innovation Systems: A Comparative Analysis*, ed. Richard R. Nelson (Oxford University Press, 1993): 115-57,122-23.

46 Otto Keck, *National System for Technical Innovation*, 136.

47 My translation of original German quote ("ungeheuren Kreativität und Experimentierfreude") from Gerold Ambrosius, "Von Kriegswirtschaft zu Kriegswirtschaft 1914-1945," in *Deutsche Wirtschaftsgeschichte*, ed. Michael North (München: C.H. Beck, 2000): 282-350. Quote found in "Wissensevolution und Forschungsgeschichte," in "Zur Technologischen Leistungsfähigkeit Deutschlands 2001," Gutachten im Auftrag des Bundesministeriums für Bildung und Forschung.

48 See Figures 1 and 5 in Hariolf Grupp, Iciar Dominguez Lacasa, and Monika Friedrich-Nishio, "Innovation and Growth in Germany in the Past 150 Years" (paper presented at the DRUID Summer Conference on "Industrial Dynamics of the New and Old Economy—Who is Embracing Whom?", Copenhagen/Elsinore, Denmark, June 6-8, 2002).

49 Otto Keck, *National System for Technical Innovation*, 136

50 Otto Keck, *National System for Technical Innovation*, 133

51 Public expenditure was raised from 1.5 percent (identical to the level that prevailed just prior to World War I) to 6.5 percent in the 1970s, although it subsequently declined.

52 However, following unification, the Federal government's share of public funding of R&D has been declining considerably.

53 The Federal Ministry of Scientific Research grew out of the Federal Ministry of Atomic Affairs, founded in 1955.

54 Hariolf Grupp, Iciar Dominguez Lacasa, and Monika Friedrich-Nishio, " Innovation and Growth in Germany in the Past 150 Years" (paper presented at the DRUID Summer Conference on "Industrial Dynamics of the New and Old Economy - Who is Embracing Whom?", Copenhagen/Elsinore, Denmark, June 6-8, 2002): 12.

55 Hariolf Grupp, "Innovationskultur in Deutschland. Wie es zur heutigen technologischen Wettbewerbsposition gekommen ist," in *Marktdynamik und Innovation—Gedächtnisschrift für Hans-Jürgen Ewers*, ed. Michael Fritsch (Berlin: Duncker & Humboldt, 2004): 21-43.

56 A critical view of Germany's export performance and the economic policies aimed at promoting export success is expressed by Adan Posen in the recent AICGS analysis "A Heavy Burden for Any Economy" (http://www.aicgs.org/analysis/c/posen081706.apx). He argues that productivity, not export competitiveness, is the proper target for economic policy. He attributes Germany's export success to real-wage compression and expanding markets, rather than increased price-competitiveness. Posen suggests that the seemingly strong export performance conceals the weakness of an over-regulated, tacitly protected and subsidized the German corporate sector, from which almost no winners in the growing high-technology and service sectors have emerged.

57 Beatrice Weder-Di Mauro, "Can Europe Compete," in *Global Competitiveness Report 2005-2006*, World Economic Forum, Geneva.

58 This view is vividly present in the account of this period given by former World Bank Chief Economist and U.S. Secretary of the Treasury Larry Summers in an interview conducted on April 24, 2001, for the PBS *Commanding Heights* website (http://www.pbs.org/wgbh/commandingheights/shared/minitextlo/int_lawrencesummers.html): "The idea that the way to get better at high tech is for the government to take over the technology industries, these kinds of ideas basically have become passé because they've been disproven. …When we came in in 1992, the dominant concern was that the United States was going to fall behind Germany, Europe, and Japan. There was a sense that those societies that were more investment-oriented, more oriented towards manufacturing production, had fewer lawyers, more scientists were directed in industrial success as their central motivation, were disciplined and tightly controlled, were the societies that were likely to succeed...[I]t was a similar intellectual error...as in 1958 after Sputnick when many people thought...that Russia would overtake the United States...By 1994 I was able to feel that it was likely to be an American decade rather than a Japanese decade."

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