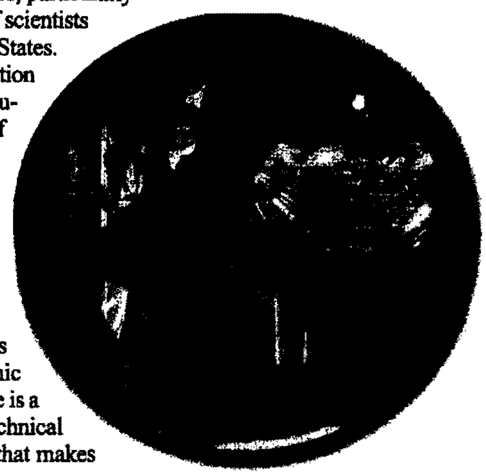
EDITORIAL

Wanted: Better Benchmarks

How much should a nation spend on science? What kind of science? How much from private versus public sectors? Does demand for funding by potential science performers imply a shortage of funding or a surfeit of performers? These and related science policy questions tend to be asked and answered today in a highly visible advocacy context that makes assumptions that are deserving of closer scrutiny. A new "science of science policy" is emerging, and it may offer more compelling guidance for policy decisions and for more credible advocacy.

All developed and many developing nations today have accepted the need to support technical education and research as keys to future economic strength. Studies from the 1990s show that U.S. investment in R&D development led to greater economic productivity, and that information technology, in particular, has been a major factor in sustaining U.S. productivity growth. The question is not whether R&D investments are important, but what investment strategies are most effective in the rapidly changing global environment for science. Here, ideas diverge.

Take the issue of the technical workforce. Sharply differing opinions exist regarding the production of U.S. scientists to meet possible impending shortages.* The differences turn on the interpretation of "benchmark" data regarding the numbers of degree holders produced in the United States and other countries, particularly China and India. In the latter countries, the rates of growth in the numbers of scientists are high, although actual numbers are small relative to those in the United States. Advocates for increased production of U.S. scientists point to our low graduation rates, whereas critics emphasize limited short-term job opportunities for graduates and postdocs. Resolution of this issue requires a broader understanding of socioeconomic factors in a number of nations that would allow us to attach probabilities to different future scenarios. Optimal strategies for large mature economies such as that of the United States will doubtless differ from those for smaller or developing economies. Here, as elsewhere in policy debates, the benchmarks do not speak for themselves.



The data we choose to collect do say something about the framework in which we understand the relations among science, government, and society. Our customary reliance on historical trends in national data, however, creates an inertia that causes data categories to lag far behind changes in the dynamic socioeconomic framework, now evolving internationally. We know that there is a complex linkage between workforce issues and other economic variables. Technical workforces in different countries are increasingly interdependent in a way that makes single-country data unreliable for workforce forecasts.

Globalization and changing modes of science that have blurred disciplinary distinctions have undermined the value of traditional science and engineering data and their conventional interpretations. The old budget categories of basic and applied R&D, still tracked by the U.S. Office of Management and Budget, do not come close to capturing information about the highly interdisciplinary activities thought to fuel innovation. A 1995 U.S. National Research Council (NRC) committee chaired by Frank Press took a step toward data reform when it introduced the combined category of "federal science and technology," declaring that "the linear sequential view of innovation is simplistic and misleading." More attention, however, is needed to definitions and models that suit current needs of policy. A recent report from the NRC Committee on National Statistics found that "the structure of . . . data collection is tied to models of R&D performance that are increasingly unrepresentative of the whole of the R&D enterprise." Further, "It would be desirable to devise, test and, if possible, implement survey tools that more directly measure the economic output of R&D in terms of short-term and long-term innovation."†

Relating R&D to innovation in any but a general way is a tall order, but not a hopeless one. We need econometric models that encompass enough variables in a sufficient number of countries to produce reasonable simulations of the effect of specific policy choices. This need won't be satisfied by a few grants or workshops, but demands the attention of a specialist scholarly community. As more economists and social scientists turn to these issues, the effectiveness of science policy will grow, and of science advocacy too.

John H. Marburger III

John H. Marburger III is director of the Office of Science and Technology Policy, Executive Office of the President of the United States, in Washington, DC.

*D. Kennedy, J. Austin, K. Urquhart, C. Taylor, *Science* **303**, 1105 (2004). †*Measuring Research and Development Expenditures in the U.S. Economy*, L. D. Brown, T. J. Plewes, M. A. Gerstein, Eds. (National Academies Press, Washington, DC, 2005).

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SCIENCE POLICY

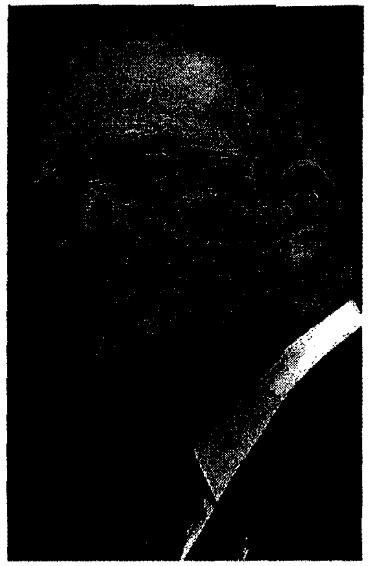
Marburger Asks Social Scientists for A Helping Hand in Interpreting Data

Will the growing number of engineers graduating from Chinese universities be a boon or bane to the United States and the rest of the world?

John Marburger would like to tell his boss, President George W. Bush, how that trend might affect the U.S. technical workforce and the country's economy—or even how long it's likely to persist. But the president's science adviser says he'd be flying by the seat of his pants. "I won't take a position on whether it's good or bad based on the data," says Marburger, "because we don't have adequate models."

Last week Marburger challenged the scientific community to help him find answers to a host of questions like these that puzzle science policymakers. "I am suggesting that the nascent field of the social science of science policy needs to grow up, and quickly," Marburger told a Washington, D.C., gathering sponsored by AAAS (which publishes *Science*). Economists have applied "behavioristic" tools successfully in other fields, says Marburger, pointing to analyses of how changes in retirement patterns might affect Social Security. He urged scientists to incorporate "the methods and literature of the relevant social science disciplines" to explore trends such as the community's "voracious appetite" for federal research funding, the "huge fluctuations" in state support for public universities, and the continuing advances in information technology.

Marburger's call to statistical arms was generally welcomed by policy analysts, who agreed that their field hadn't made much progress on the big questions confronting decision makers. "We operate with blinders on," says Daniel Sarewitz of Arizona State University in Tempe, a former congressional staffer who studies the interplay of science and society. "Rather than simply tracking the growth in industrial R&D, for example, we also need to look at how that affects public sector investment. The set of assumptions that goes into S&T policy is unbelievably oversimplified."



Supermodel. U.S. science adviser John Marburger wants better econometric models of research trends.

That lack of rigor, speculates Harvard economist Joshua Lerner, part of a group studying U.S. innovation policy, could be a result of the limited interaction between the disciplines. "A lot of science policy has an amateur-hour flavor to it because it's done by scientists who aren't familiar with the principles of the social sciences," he says. "But it's also our fault. We economists haven't communicated as well with other disciplines as we should."

Another factor is the sheer difficulty of coming up with a theoretical framework that takes into account enough of the important variables to generate useful results. "Such a model has proved to be elusive," says Rolf Lehming, who oversees the National Science Foundation's biennial volume: *Science and Engineering Indicators*. Previous efforts to nurture such a community of scholars were abandoned, notes Mary Ellen Mogee, a science policy analyst at SRI International in Arlington, Virginia, including the 1995 elimination of the congressional Office of Technology Assessment.

Marburger says that he believes a new effort can be mounted at minimal cost. "We're not talking about a lot of money; ... funding is not a rate-limiting factor in this equation." But others see a federal role as crucial. Connie Citro, who directs the National Academies' Committee on National Statistics, says that "there needs to be at least a signal [from the federal government] that proposals would be welcome." Sarewitz admits that a plea for federal support is self-serving, but he adds, "that's what drives academics in any field."

–JEFFREY MERVIS

Rising Above The Gathering Storm:
Energizing and Employing America for a Brighter Economic Future [Excerpts]

Statement of

Norman R. Augustine
Retired Chairman and Chief Executive Officer
Lockheed Martin Corporation

And

Chair, Committee on Prospering in the Global Economy of the 21st Century
Committee on Science, Engineering, and Public Policy
Division on Policy and Global Affairs
The National Academies

before the

Committee on Science
U.S. House of Representatives

October 20, 2005

Mr. Chairman and members of the Committee.

Thank you for this opportunity to appear before you on behalf of the National Academies' Committee on Prospering in the Global Economy of the 21st Century. As you know, our effort was sponsored by the National Academy of Sciences, National Academy of Engineering and Institute of Medicine (collectively known as the National Academies). The National Academies were chartered by Congress in 1863 to advise the government on matters of science and technology.

The Academies were requested by Senator Alexander and Senator Jeff Bingaman, members of the Senate Committee on Energy and Natural Resources to conduct an assessment of America's ability to compete and prosper in the 21st century—and to propose appropriate actions to enhance the likelihood of success in that endeavor. This request was endorsed by Representatives Sherwood Boehlert and Bart Gordon of the House Committee on Science.

To respond to that request the Academies assembled twenty individuals with diverse backgrounds, including university presidents, CEOs, Nobel Laureates and former presidential appointees. The result of our committee's work was examined by over forty highly qualified reviewers who were also designated by the Academies. In undertaking our assignment we considered the results of a number of prior studies which were conducted on various aspects of America's future prosperity. We also gathered sixty subject-matter experts with whom we consulted for a weekend here in Washington and who provided recommendations related to their fields of specialty.[. . . .]

• U.S. companies each morning receive software that was written in India overnight in time to be tested in the U.S. and returned to India for further production that same evening—making the 24-hour workday a practicality.

• Back-offices of U.S. firms operate in such places as Costa Rica, Ireland and Switzerland.

• Drawings for American architectural firms are produced in Brazil.

• U.S. firm's call centers are based in India—where employees are now being taught to speak with a mid-western accent.

• U.S. hospitals have x-rays and CAT scans read by radiologists in Australia and India.

• At some McDonald's drive-in windows orders are transmitted to a processing center a thousand miles away (currently in the U.S.), where they are processed and returned to the worker who actually prepares the order.

• Accounting firms in the U.S. have clients tax returns prepared by experts in India.

• Visitors to an office not far from the White House are greeted by a receptionist on a flat screen display who controls access to the building and arranges contacts—she is in Pakistan.

• Surgeons sit on the opposite side of the operating room and control robots which perform the procedures. It is not a huge leap of imagination to have highly-specialized, world-class surgeons located not just across the operating room but across the ocean. [. . .]

• In 1997 China had fewer than fifty research centers managed by multinational corporations. By 2004 there were over six-hundred.

• Two years from now, for the first time, the most capable high-energy particle accelerator on earth will reside outside the United States. [. . .]

• In 2003 foreign students earned 59% of the engineering doctorates awarded in U.S. universities.

[. . . .]

http://www7.nationalacademies.org/ocga/testimony/Gathering_Storm_Energizing_and_Employing_America2.asp

From Jeffrey T. Macher and David C. Mowry (Eds.), **Innovation in Global Industries: U.S. Firms Competing in a New World (Collected Studies).** Washington, DC: National Academies Press, 2008), pp. ix – xi.

Preface and Acknowledgments

In 1999 the National Academies' Board on Science, Technology, and Economic Policy (STEP) released a series of industry studies analyzing the sources of competitive resurgence from the 1980s to the 1990s of many U.S.-based firms in a variety of manufacturing and service sectors. These studies, published under the title *U.S. Industry in 2000: Studies in Competitive Performance*, included steel, chemicals, metal working, trucking, grocery retailing, retail banking, computing, semiconductors, hard disk drives, apparel, pharmaceuticals, and biotechnology.

The general picture of stronger performance in the mid-to-late 1990s than in the early 1990s was attributed to a variety of factors including heavy investment in applications of information technology, supportive public policies, openness to innovation, and changes in supplier and customer relationships. Vigorous foreign competition forced cost-cutting changes in manufacturing processes, organization, and strategy but then receded, making the performance of U.S. industries look even better. As none of these favorable conditions could be assumed to be permanent, the collected studies persuasively made the point that U.S. industries' superior performance is not guaranteed to continue.

In late 2005 the STEP Board decided to reprise the study, focusing on the acceleration in global sourcing of innovation and emergence of new locations of research capacity, new sources of skilled technical workers, and the implications of these developments for U.S. businesses and workforce. Although the current study involves several of the same industries—in particular, semiconductors, personal computing, financial services, pharmaceuticals, and biotechnology—the overall selection shifted markedly toward technology-intensive producing, supporting, or using sectors to include software, flat panel displays, solid state lighting, logistics, and venture capital finance. The group of industries examined does not represent a carefully selected sample representative of the economy as a whole. Rather, it reflects a decision to again capitalize on the work of university-based multidisciplinary research teams studying economic performance and technological change at the industry level. Most of these groups were formed and supported under the Industry Centers Program of the Alfred P. Sloan Foundation.

To help integrate this work, the Board again asked **David C. Mowery**, Professor at the Haas School of Business at the University of California at Berkeley, to develop a general framework for analyzing changes in the structure of innovation over the past 10 to 15 years. Mowery in turn recruited **Jeffrey T. Macher**, Associate Professor, McDonough School of Business, Georgetown University, to assist in this effort and co-edit the resulting volume. The chapters in this volume were drafted independently by individual authors, and their findings and any policy recommendations do not represent a consensus among all of the contributors to the volume. They also do not necessarily represent the opinions and views of the Committee on Competitiveness and Workforce Needs of U.S. Industry, the STEP Board, the National Academies, or the sponsoring organizations.

In the course of their work, the editors and chapter authors participated in two public workshops in Washington, D.C. The first, on April 19, 2006, reviewed their preliminary findings with industry representatives and other analysts including **Irving Wladawsky-Berger**, IBM Corporation; **Jack Gill**, Vanguard Ventures and Harvard Medical School; **Richard S. Golaszewski**, GRA, Inc.; **Jeffrey D. Tew**, General Motors; **Jerome H. Grossman**, LionGate Corporation and Harvard University; **Gordon W. Day**, Optoelectronic Industry Development Association; **Timothy J. Sturgeon**, Massachusetts Institute of Technology; **Charles W. Wade**, Technology Forecasters, Inc.; **Richard B. Freeman**, Harvard University; **Nancy Hauge**, K12; **Harold Salzman**, the Urban Institute; and **Navi Radjou**, Forrester Research, Inc.

A year later a second workshop was held, on April 20, 2007, to try to anticipate trends over the next several years in three broad sectors encompassing most of the industries being studied—information and computing technology, biopharmaceuticals, and finance. Speakers in addition to committee members and authors included **Undersecretary Robert C. Cresanti**, Commerce Department's Technology Administration; **Barry Jaruzelski**, Booz Allen Hamilton; **Robert D. Atkinson**, Information Technology and Innovation Foundation; **Alex SooJung-Kim Pang**, Institute for the Future; **Bhaskar Chakravorti**, McKinsey and Company; **David Moschella**, Leading Edge Forum; **Michael E. Fawkes**, Hewlett-Packard Company; **Anna D. Barker**, National Cancer Institute; **Thomas R. Cech**, Howard Hughes Medical Institute; **Joseph Jasinski**, Health Care Life Science, IBM; **Andy Lee**, Pfizer Inc.; **T. L. Stebbins**, Canaccord Adams, Inc.; **Karen G. Mills**, Solera Capital; and **Alex J. Pollock**, American Enterprise Institute.

As the editors state in their summary introduction to this collection, despite the emergence of robust R&D and innovative capabilities in East, Southeast, and

South Asia, and concerted efforts to develop them in other parts of the world, patterns of innovation are highly variable across industries and across firms within industries. Many industries and some firms within nearly all industries retain leading-edge capacity in the United States. The flat panel display sector, in which innovative activity for the most part has followed production abroad, is not as yet the norm. This is no reason for complacency about the outlook for the future, however. Empirically-based analyses such as those in this volume are inevitably backward-looking. Even recently issued patents generally represent filings two to five years back and R&D investments considerably earlier. Although not pessimistic overall, our authors compellingly document the rapidity of contemporary industrial change and shifts in competitive advantage. For that reason alone, innovation deserves more sustained public policy attention than it has been receiving.

The STEP Board is grateful to the authors, the editors, and the workshop participants as well as to the sponsors of this activity—**the Alfred P. Sloan Foundation**, the **U.S. Department of Education**, and the **Technology Administration of the U.S. Department of Commerce.**

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

We wish to thank the following individuals for their review of this report: **Suma Athreye**, Brunel University; **MaryAnn Feldman**, University of Toronto; **Jeffrey Furman**, Boston University; **Bronwyn Hall**, University of California at Berkeley; **Megan MacGarvie**, Boston University; **Deepak Somaya**, University of Maryland; **Jerry Thursby**, Emory University; and **Philip Webre**, Congressional Budget Office.

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

David T. Morgenthaler, *Chair*
Stephen A. Merrill, *Study Director*

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future (2007)
Committee on Science, Engineering, and Public Policy (COSEPUP)

Executive Summary

India, or dozens of other nations whose economies are growing. This has been aptly referred to as "the Death of Distance."

CHARGE TO THE COMMITTEE

The National Academies was asked by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, with endorsement by Representative Sherwood Boehlert and Representative Bart Gordon of the House Committee on Science, to respond to the following questions:

What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?

The National Academies created the Committee on Prospering in the Global Economy of the 21st Century to respond to this request. The charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen the quality of life in America—our prosperity, our health, and our security. The committee has been cautious in its analysis of information. The available information is only partly adequate for the committee's needs. In addition, the time allotted to develop the report (10 weeks from the time of the committee's first gathering to report release) limited the ability of the committee to conduct an exhaustive analysis. Even if unlimited time were available, definitive analyses on many issues are not possible given the uncertainties involved.[2]

This report reflects the consensus views and judgment of the committee members. Although the committee consists of leaders in academe, industry, and government—including several current and former industry chief executive officers, university presidents, researchers (including three Nobel prize winners), and former presidential appointees—the array of topics and policies covered is so broad that it was not possible to assemble a committee of 20 members with direct expertise in each relevant area. Because of those limitations, the committee has relied heavily on the judgment of many experts in the study's focus groups, additional consultations via e-mail and telephone with other experts, and an unusually large panel of reviewers.

2 Since the prepublication version of the report was released in October, certain changes have been made to correct editorial and factual errors, add relevant examples and indicators, and ensure consistency among sections of the report. Although modifications have been made to the text, the recommendations remain unchanged, except for a few corrections, which have been footnoted.