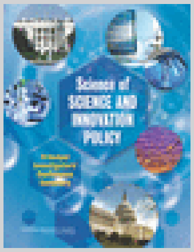

Science of Science and Innovation Policy: Principal Investigators' Conference Summary

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Kaye Husbands Fealing, Alexandra S. Beatty, and Constance F. Citro, Rapporteurs; Steering Committee on the Science of Science and Innovation Policy Principal Investigatorsâ€™ Conference; Committee on National Statistics; Division of Behavioral and Social Sciences and Education; National Research Council

Science of SCIENCE AND INNOVATION POLICY

Principal Investigators' Conference Summary

Steering Committee on the Science of Science and Innovation Policy
Principal Investigators' Conference

Kaye Husbands Fealing, Alexandra S. Beatty, and Constance F. Citro, *Rapporteurs*

Committee on National Statistics
Division of Behavioral and Social Sciences and Education

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2013-2014

Acknowledgments

This conference was organized by a steering committee composed of expert social, behavioral, and economic scientists. The steering committee provided invaluable guidance during the course of developing the conference, in the process of securing expert presentations, and in facilitating the conduct of the conference. This multidisciplinary committee reflected many qualities of the SciSIP researcher community and the policy makers that SciSIP research is meant to inform. With heartfelt gratitude, the rapporteurs thank the following committee members: Irwin Feller, committee chair, senior visiting scientist at the American Association for the Advancement of Science, emeritus professor of economics at The Pennsylvania State University, former director of the Institute for Policy Research and Evaluation, and specialist on design, governance, and evaluation of national science systems; Gregory Feist, associate professor of psychology in personality and adult development in the Department of Psychology at San José State University, founding president of the International Society for the Psychology of Science and Technology, and founding editor-in-chief of the *Journal of Psychology of Science & Technology*; Benjamin Martin, professor of science and technology policy studies in SPRU (Science and Technology Policy Research), University of Sussex, specialist adviser to the House of Lords Select Committee on Science and Technology, and editor of *Research Policy*; Laurel Smith-Doerr, professor of sociology and director of the Institute for Social Science Research, University of Massachusetts-Amherst, and specialist on interdisciplinary research and organizations; Marie Thursby, Hal and John Smith chair in entrepreneurship at the College of Management, Georgia Institute of Technology, specialist on multinational R&D, technology entrepreneurship, and technology transfer; and James Turner, Jr., senior counsel and director of the energy program at the Association of Public and Land-grant Universities, who spent 30 years working with the House of Representatives' Committee on Science and Technology as chief counsel, technology staff director. Although the steering committee members played a central role in designing and conducting the workshop, they did not actively participate in writing this summary.

We also recognize the excellent work of the staff of the NRC for support in developing and organizing the conference, particularly Anthony Mann, program coordinator for the Committee on National Statistics.

This conference summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published summary as sound as possible and to ensure that the summary meets institutional standards for clarity, objectivity and responsiveness to the charge. The review comments and draft manuscript remain confidential to protect the integrity of the process. We wish to thank the following individuals for their review of this workshop summary: Norman H. Bradburn, NORC, The University of Chicago; and Stephanie S. Shipp, Social and Decision Analytics Laboratory, Virginia Bioinformatics Institute, Virginia Tech.

Although the reviewers listed above have provided many constructive comments and suggestions, they did not see the final draft of the workshop summary before its release. The review of this summary was overseen by Sallie Keller, Virginia Bioinformatics Institute at Virginia Tech. Appointed by the National Research Council, she was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the rapporteurs and the institution.

Kaye Husbands Fealing, *Study Director*
Steering Committee on the Science of
Science and Innovation Policy Principal
Investigators' Conference

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Introduction and Background

Science and innovation policy makers have long had a keen interest in obtaining quantitative data and qualitative information they can use to support decisions they make, such as whether and how much to invest in graduate training programs or in research and development. (Box 1-1 lists some of the issues of concern to science policy makers.)

BOX 1-1
Selected Illustrative Issues for Science and Innovation Policy

Competitiveness What internal and external factors help predict competitiveness of a nation or region? What are the effects of gain or loss of productive capacity in an industry on basic scientific infrastructure? What may be the long-term effects in the United States of the disappearance of big private-sector research labs doing basic research?

Data Extraction and Manipulation What is the value of new data, metrics, and indicators that are becoming available to illuminate science and engineering policy questions?

Geospatial Clusters Where are regional and international hot spots for basic research and innovative activities? What metrics of science and engineering resources and networks reliably indicate regions and countries to watch for scientific and technological breakthroughs?

Innovation What is known about the dynamics of innovation? What speeds or slows the diffusion of new ideas and new applications across countries or across firms? Under what circumstances, if at all, can public policy or infrastructure affect the speed of diffusion?

Role of Government What are the effects of government efforts to promote innovation in the manufacturing sector and in the service sector? When can public policy or infrastructure affect the speed of diffusion of new scientific knowledge? Are there sectors where the long-term social and economic benefits are great enough to justify major government investment in "jump-starting" a given sector? What is the expected employment yield (jobs, wages, and occupational mobility) of public expenditures on science and technology?

Strategic Policy Design What can be learned from successful and unsuccessful efforts to coordinate federal science and technology policy? What can be learned from analogous private sector activities, such as the creation of cross-functional teams?

Technology Transfer Under what circumstances is academic research effectively translated into private-sector applications? Can universities do more to transfer technology to the marketplace? What institutional and legal changes are needed to bridge the "valley of death" between the university and private industry? What is the link between scientific discoveries at academic institutions and private sector job creation?

Transformative Research What mechanisms can encourage researchers to identify high-impact multidisciplinary research opportunities that are being underfunded?

SOURCE: Compiled by Kaye Husbands Fealing, workshop summary rapporteur and original NSF program director for SciSIP.

At the same time, researchers in many disciplines—including chemistry, computer science, economics, engineering, physics, political science, psychology, sociology, and visual analytics—have worked to understand the factors underlying scientific discovery and technological innovation, but researchers and policy makers have not always communicated or collaborated effectively. In 2005, U.S. Science Advisor John Marburger, III, called for a multidisciplinary approach to both create an evidentiary platform for science policy and develop a formal field of study (Marburger, 2005).[1]

Heeding this call, as well as heightened interest from both policy makers and researchers, the National Science Foundation developed the Science of Science and Innovation Policy program (SciSIP) in 2006.[2] This program funds basic and applied research that bears on and can help guide public- and private-sector policy making for science and innovation. By design, SciSIP has engaged researchers from many domains in the development of a community of practice in this new field—that is, a cadre of experts who work together to continually develop frameworks, tools, and datasets for implementing science and innovation policy. Since its inception, the SciSIP program has funded more than 150 researchers and their graduate students. The program also contributed to the initiation of the STAR METRICS (Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science) program, a collaborative effort between the National Science Foundation and the National Institutes of Health. The STAR METRICS program develops tools and mechanisms for measuring federal expenditures on scientific activities, with particular focus on quantifying productivity and employment outcomes.

Having made five rounds of research awards, the SciSIP program directors recognized the need for a summative showcase of the productivity and contributions of

[1]Dr. Marburger was U.S. science advisor and director of the White House Office of Science and Technology Policy (OSTP) in the second Bush administration, a position he held from 2001–2009. He delivered the address where he effectively called for the emergence of the science of science policy field at the American Association for the Advancement of Science Forum on science and technology policy in Washington, DC, on April 21, 2005. To read the content of the speech, see http://scienceofsciencepolicy.net/reference/marburger-speech-aaas-forum-science-and-technology-policy [January 2014]. Dr. Marburger passed away in July 2011. To read a brief biography, see http://www.stonybrook.edu/sb/marburger/obit.shtml [January 2014].

[2]For more information about SciSIP, see http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501084 [January 2014].

SciSIP researchers, who have investigated many long-standing questions regarding investment in and organization of science, engineering, and innovation in the United States and in other nations. As part of that activity, the program directors asked the Committee on National Statistics (CNSTAT) of the National Academy of Sciences/National Research Council to convene a two-day public conference. CNSTAT formed the Steering Committee on the SciSIP Principal Investigators' Conference. The committee was charged to plan a conference that would present research funded by SciSIP and foster intellectual exchange among funded researchers, science, technology, and innovation policy practitioners, and other members of the science community. The conference was the largest gathering of SciSIP principal investigators since the program's inception. (See Box 1-2 for the steering committee charge.)

BOX 1-2
Statement of Task for the SciSIP Conference Steering Committee

An ad hoc committee will plan and conduct a two-day public workshop to foster intellectual exchange among funded researchers of the National Science Foundation's (NSF) Science of Science and Innovation Policy Program (SciSIP) and between these researchers and science, technology and innovation policy practitioners. In keeping with the goals of the SciSIP program, this workshop will facilitate scholarly exchanges between SciSIP award recipients. It is intended to be the largest gathering of SciSIP principal investigators since the inception of the program in 2006. The fifth year of the program is the opportune time to showcase its research productivity and contributions to many long-standing questions regarding investment in and organization of science, engineering and innovation activities in the U.S. and in other nations.

The workshop will feature invited presentations and discussions. It may also include poster sessions. The committee will develop the agenda for the workshop, select and invite speakers and discussants, and moderate the discussions. Topics to be addressed at the event will highlight advances in the emerging field of the science of science and innovation policy. In particular, models, frameworks, tools, and datasets comprising the evidentiary basis for science and innovation policy will be the focus of the event. The workshop, therefore, will not only facilitate interdisciplinary discourse between researchers from a variety of academic disciplines and fields, it will also foster communication and learning between academicians and policymakers, thereby advancing the development of the SciSIP community of practice. Presentations by SciSIP researchers will focus on several themes, such as: return on investment models; organizational structures that foster accelerated scientific productivity; linkages between commercialized scientific knowledge and job creation; the roles of universities and government in technology transfer and innovation; technology diffusion and economic growth; non-economic impacts of science and innovation expenditures; regional and global networks of knowledge generation and innovation; mechanisms for encouraging creativity and measuring outputs and outcomes from transformative research; and development, manipulation and visualization of data representing scientific activities. A designated rapporteur will prepare an independently-authored summary of the workshop.

ORGANIZATION OF THE CONFERENCE AND THIS SUMMARY

The SciSIP Principal Investigators' Conference included presentations and roundtable discussions, data use demonstrations, and poster sessions.[3] It highlighted models, frameworks, tools, and datasets that are in varying stages of development towards the goal of improving the evidentiary basis for science and innovation policy. Three plenary sessions brought together policy makers from different scientific domains and areas of influence, experts from the natural sciences that are often studied by SciSIP researchers, and SciSIP researchers who have produced results that have been useful in the policy domain. Nine concurrent sessions highlighted advances in various substantive and methodological domains of the emerging field of the science of science and innovation policy. Topics addressed included: implementing science policy; scientific discovery processes; human capital; organizations, institutions, and networks; innovation (two sessions); data extraction and measurement; mapping science; and assessment and program evaluation. The agenda was structured to allow ample opportunities for informal discussion and collaboration.

This report has been prepared by the conference rapporteurs as a factual summary of what occurred at the conference. The steering committee's role was limited to planning and convening the conference. The views contained in the report are those of individual conference participants and do not necessarily represent the views of all conference participants, the steering committee, or the National Research Council.

The summary is organized as follows. Because a basic grasp of the history of the SciSIP program is helpful to understanding the role of the SciSIP Principal Investigators' Conference and where the field stands at present, the remainder of this first chapter summarizes that history. Chapter 2 summarizes points made by invited policy makers about SciSIP and its context and goals. Chapters 3 through 5 summarize presentations of the SciSIP researchers who described their work.[4] Rather than be presented sequentially according to the workshop agenda, these summaries have been arranged according to three broad themes—incentives, governance, and innovation, work and collaboration, and 21st century data—but it is important to note that the projects discussed were completely independent of one another. The closing chapter summarizes the perspectives of speakers who were invited to reflect on the SciSIP-funded research and its significance. The conference agenda and participant list appear in Appendix A. Papers commissioned for the conference, presentations, and other materials are available on the CNSTAT website.[5]

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[3]The steering committee endeavored to identify a representative group of PIs, reflecting a range of topics, who had findings to share, could be accommodated within the limited time of the conference, and who were available on the scheduled dates. The opportunity to make a poster presentation was offered to all PIs who were not giving formal presentations.

[4]Poster session discussions are not summarized in this report. Lists of all SciSIP awards appear in Appendix B. Abstracts of these research projects are readily available on NSF's website at http://nsf.gov/awardsearch/ [January 2014].

[5]See http://sites.nationalacademies.org/DBASSE/CNSTAT/CurrentProjects/DBASSE_072054 [January 2014]. The three commissioned papers are: Erin Leahey, "Shaping Scientific Work: The Organization of Knowledge Communities"; Dean Simonton, "Assessing Scientific Creativity: Conceptual Analyses of Assessment Complexities"; and Albert Teich, "Making Policy Research Relevant to Policy."

HISTORY OF SciSIP

The 2005 path-breaking speech by U.S. Science Advisor John Marburger, III, provided the impetus for bringing together what were previously scattered areas of research on the drivers of science and innovation in order to develop a full-fledged field of study with appropriate frameworks, tools, and datasets.[6] NSF responded immediately by taking steps to set up SciSIP. (See the timeline in Figure 1-1.)

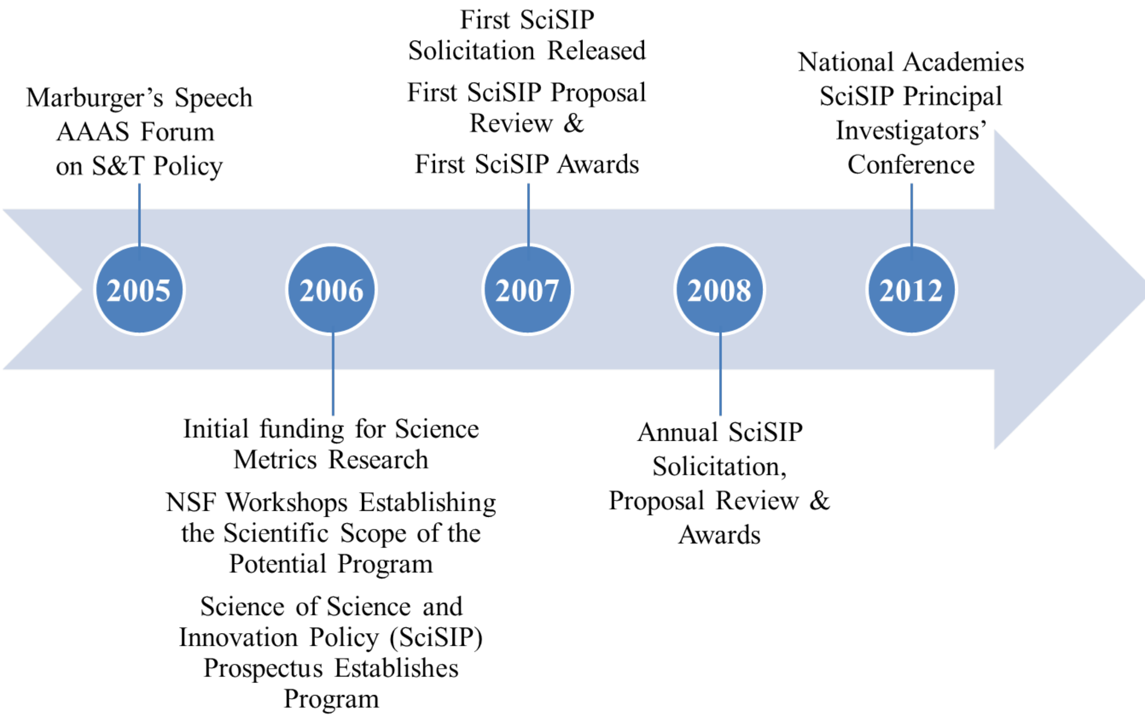

FIGURE 1-1 Timeline of the SciSIP program's development, 2006-2012.

At the outset, research communities within the purview of the NSF Directorate of Social, Behavioral, and Economic Sciences (SBE) were asked for input on the possible development of this new funding activity. This bottom-up approach is what NSF follows to ensure that the goals and objectives of new activities are commensurate with what researchers foresee as feasible and within their purview. The three divisions within SBE—Behavioral and Cognitive Sciences (BCS), Science Resources Statistics (SRS, now known as the National Center for Science and Engineering Statistics, NCSES), and Social and Economic Sciences (SES)—each convened a workshop during the spring-summer of 2006.[7] Although the three workshops addressed opportunities for different

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[6]Several conference participants reflected on the importance of Marburger's speech in light of long-standing discussions on funding priorities among scientific disciplines and other difficult issues of science policy (see Chapter 2).

[7]BCS and SES are research-sponsoring divisions, while SRS, now NCSES, is the data repository of national science and engineering statistics. At the time of SciSIP's development, David Lightfoot was SBE

strains of research, their purposes were the same: to obtain input on how research communities would approach the task of developing scientific platforms for deliberative science and innovation policy decisions.

The BCS workshop focused on the possible contributions to a science of science and innovation policy of an emerging field of research in which psychologists and engineers collaborate on models of the engineering design process (Schunn et al., 2006). This work can guide the development of creativity models and provide explanations of "the scientific bases of individual and team innovation and discovery" (the title of the workshop report). It also provides a basis for optimizing the organization of science labs and other collaborative basic research and innovation activities. This research community expected their contribution to the science of science and innovation policy to be:

- studies that expand understanding of the cognitive mechanisms of innovation/creativity and the ways in which strategies and external tools influence these cognitive mechanisms;
- computational modeling and agent simulations of innovation/creativity that allow for theoretical development for analysis at multiple levels (individuals, groups, and organizations);
- empirical studies and computational models that explore the temporal dynamics of individual and group factors on innovation/creativity;
- interdisciplinary programs of research that coordinate experiments in psychology laboratories and engineering design; and
- empirical studies that examine the cognitive, social, and motivational factors of group cognition in more realistic group settings.

SES convened a workshop to determine the potential contributions of its research community to a science of science and innovation policy (Cozzens, Regan, and Rubin, 2007). Attendees represented several disciplines, including economics, ethics, history of science, science and technology studies, and sociology. Collectively, they articulated the following areas that are ripe for research that could assist science and innovation decision making:

- linkages of scientific advances and innovation to economic growth, productivity, and other measures of economic and social well-being;
- institutional and organizational environments that foster or forestall innovation and creativity;
- the political economy of science, technology, and innovation policy;
- evidence and expertise in science-intensive decision making; and
- the impact of science, technology, and innovation on global economic, social, and environmental change.

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assistant director and Mark Weiss, Edward Hackett, and Lynda Carlson directed the BCS, SES, and SRS divisions, respectively. SRS became the National Center for Science and Engineering Statistics in January 2011.

Marburger's call for a science of science policy included a clear appeal for more comprehensive, directly applicable, and timely datasets in science, engineering, technology, and innovation inputs, outputs, outcomes, and practices at the sub-national, national, and international levels. The Science Resources Statistics Division hosted a workshop entitled "Advancing Measures of Innovation: Knowledge Flows, Business Metrics, and Measurement" (NSF, 2006). That workshop yielded several areas for which metrics are in need of further development or are not yet in existence, including:

- innovation activities in and outside of research and development (R&D) labs;
- key drivers, inputs, and institutional mechanisms for R&D, such as spending decisions, market demand, social needs, and knowledge management;
- outputs, outcomes, adoption, and diffusion of innovations;
- effects of government policies on innovation;
- relationships, knowledge flows, and networks, particularly between universities and industry;
- measurement of intangible assets and disembodied knowledge;
- mobility of individual scientists and graduate students; and
- means by which data can be made accessible in a timely fashion and in a secure environment that protects privacy and confidentiality to researchers and other data users.

The information gathered through these three workshops was digested and ultimately incorporated in a prospectus for the SciSIP program issued by NSF at the launch of the program in the fall of 2006. SciSIP initially had three goals: (1) develop usable knowledge and theories of creative processes and their transformation into social and economic outcomes; (2) improve and expand science metrics, datasets, and analytical tools, yielding changes in the biannual science and engineering indicators and other data collections; and (3) develop a community of experts across the federal government, industry, and universities focused on SciSIP.[8]

In February 2007, SciSIP issued its first solicitation for research proposals, and the first awards (19 in all) were made in August 2007. The projects can be categorized as follows: human capital development and the collaborative enterprise; returns to international knowledge flows; creativity and innovation; knowledge production systems; and implications of science policy. The program has grown in subsequent years. In 2008, eight of the 24 funded projects focused on innovation, specifically the role of firms in innovation and measuring and tracking innovation. The 2009 and 2010 solicitations included specific requests for proposals on data development, manipulation, and visualization. At the time of the conference, SciSIP had funded 91 projects based on its core solicitation and 12 RAPID awards in response to its 2009 "dear colleague" letter regarding measures of impacts related to the American Recovery and Reinvestment Act (ARRA or Stimulus Package).[9] SciSIP principal investigators have also published dozens of peer-reviewed articles and contributed several datasets to the general research

[8]See the project prospectus, http://www.nsf.gov/sbe/scisip/scisip_prospectus.pdf [January 2014].

[9]Since the conference, SciSIP funded two more rounds of awards, bringing the total number of awards to 155, including RAPID awards.

community. The results of these projects were the focus of the conference, for which the proceedings are summarized in the remainder of this report.

2

Opening Sessions

This chapter summarizes the remarks of the four speakers who opened the conference and set the stage. It then summarizes the remarks of the four panelists in the first plenary roundtable session, which highlighted the views of science and innovation policy makers who are the ultimate consumers of the output of research conducted under the Science of Science and Innovation Policy (SciSIP) program. The concluding section is a summary of the discussion that followed the panelists' remarks.

SETTING THE STAGE

The opening session of the SciSIP Principal Investigators' Conference set forth the purposes of the conference and provided additional historical background. Speakers included Irwin Feller, professor emeritus of economics at the Pennsylvania State University and chair of the conference steering committee; Charles Vest, then president of the National Academy of Engineering (NAE, one of the constituents of the National Academies complex); Constance Citro, director of the National Research Council (NRC)'s Committee on National Statistics (CNSTAT), under whose auspices the conference was organized; and Myron Gutmann, then director of the National Science Foundation (NSF)'s Social, Behavioral and Economic Sciences (SBE) directorate.

Remarks of Irwin Feller, Pennsylvania State University

Irwin Feller described three overlapping and reinforcing agendas for the conference. The first was the formal agenda (see Appendix A), which was designed to help foster an intellectual exchange among funded researchers of the NSF SciSIP program and between these researchers and science policy practitioners. The second was an informal agenda to provide each participant an opportunity to meet and talk with colleagues and others who share a common interest in science and innovation policy, thereby helping to build the community of practice that is a central objective of the NSF SciSIP program. It was for this reason that the conference contained a mix of plenary sessions, breakout sessions, poster sessions, breaks, and conference-provided meals.

Feller stated that the third agenda was a personal one, in which the conference contributed to his own ongoing longitudinal study of the evolution of the science of science and innovation policy that began 50 years ago. It was in 1962 that the National Bureau of Economic Research (NBER) published the seminal volume *The Rate and Direction of Inventive Activity: Economic and Social Factors* (National Bureau of

Economic Research, 1962). He observed that the section and chapter headings in that volume read like the titles of today's conference and many of its presentations—for example, Problems of Definition and Measurement, The Economics of Research and Development, The Changing Direction of Research and Development Employment Among Firms, and The Link Between Science and Invention. Many of today's conference participants probably studied with people who authored the chapters in the NBER volume; some were taught by people who studied with those people; while some may have no idea what this volume refers to, but essentially have absorbed it as part of the ethos regarding the fundamental assumptions of science and innovation policy. Feller noted his own modest role in the conference that produced the NBER volume as the graduate assistant of one of the co-organizers. From that beginning, he maintained a continuing curiosity about how the field has advanced over this 50-year period, as well as to what extent it has contributed and has relevance to policy making. He called this conference a data point for his study by shedding light on what has been learned from the SciSIP initiative that is new, significant, and relevant.

Equally important in the advancement of the science of science and innovation policy field is the extent to which academic researchers and science and technology policy makers engage in productive interactive dialogue. Feller said one can dispense with a linear model in which knowledge flows downstream or downhill from academic research to policy makers. In fact, from previous workshops organized under the SciSIP program, it is clear that policy makers have a keen interest in the work that is being done through SciSIP and related initiatives (Teich and Feller, 2009, 2011). What policy makers would like first, he suggested, is some kind of translation so that research findings are comprehensible. Second, they would like a consumer report-type digest to see which of several competing models that deal with the same issues are more accurate or more relevant. But more importantly, the issues that policy makers wrestle with represent cutting edge challenges to the research community. Indeed, one of the continuing challenges to the SciSIP and cognate research communities is to see if it is possible to answer the questions posed by the late Dr. John H. Marburger, III, in his now-famous speech about the need for a science of science policy (Marburger, 2005).

Remarks of Charles Vest,[10] National Academy of Engineering

Charles Vest identified three conundrums for science policy making. First, from the perspective of the federal government and in particular Congress, scientific research is supported as a means to an end—namely, to improve the economy, national health, national security, and other national goals. Yet, he observed, that may not be what motivates bright young scientists. They are driven in general by something totally different, such as intellectual curiosity, the thrill of the chase, and the deep burrowing into a very challenging intellectual problem. Somehow, he said, science policy making has to bring these two interests together in a way that drives the country forward.

Vest noted that policy makers face another conundrum in deciding whether to

[10]Dr. Charles Vest, former president of the National Academy of Engineering, passed away in December 2013. For his brief biography, see http://www.nae.edu/Projects/MediaRoom/News/105530.aspx [January 2014].

invest in research directed to short-term or long-term results. He predicted that the future would see a lot more work in “Pasteur’s fourth quadrant” (Stokes, 1997): work that advances fundamental knowledge but also has an end goal in mind. Prime examples include not only the work of Louis Pasteur, but also the work at Bell Labs that advanced the science of physics and led to the transistor and all of the inventions that this new technology spawned (see Gertner, 2012). Yet a third conundrum is how to differentiate between what is a cost and what is an investment. Researchers all believe that funding for their work is an investment, but that is not always so obvious to policy makers.

Vest concluded by expressing his view that the role of science policy is to deal with these conundrums in a rational way, by drawing on metrics from research that explain the past and provide guides to the future and balancing those metrics with judgment. At the end of the day, the big issue is communication between the researcher community and policy makers. He challenged the conference participants to understand the issues facing science policy makers and articulate them in a way that people who are not part of the research community or particularly sympathetic to that community can begin to understand them.

Remarks of Constance Citro, National Research Council

Constance Citro noted that a CNSTAT review of statistics on research and development (R&D) spending, commissioned by the National Center for Science and Engineering Statistics, contributed in a small way to launching the SciSIP program (National Research Council, 2005). The report recommended improvements in NCSES surveys about R&D expenditures and that NCSES pursue measurement of innovation. When briefed on the report, Marburger lamented that economic policy makers had the support of economists, who could bring to bear an array of data and macro and micro models. While the models were not always accurate, nonetheless, a whole toolbox was available to help policy makers evaluate the likely costs and benefits of different fiscal policies, tax and transfer programs, and so on. In contrast, Marburger felt that research in the area of science policy was in its infancy and had not achieved the scope and scale required.

Marburger’s subsequent speech to the American Association for the Advancement of Science (AAAS) catalyzed the launching the SciSIP program at NSF within SBE. Kaye Husbands Fealing, who organized this conference, did the intellectual and logistical work that made it possible to initiate the program. She was followed by Julia Lane, now at the American Institutes for Research, then by David Croson, and now Joshua Rosenbloom.

Citro concluded by expressing the hope that the SciSIP program would generate longitudinal time series that could support research on what works in this very complex arena of science and technology policy. She stressed the importance that microdata sets be shared widely within the research community.

Remarks of Myron Gutmann, National Science Foundation and University of Michigan

Myron Gutmann reminded the conference participants of how unique the SciSIP program is. It is multidisciplinary, it incorporates a variety of sciences, it orients basic research toward immediate application to support informed policy, and it has accomplished a great deal in its short history. He said NSF expects that this multidisciplinary approach is going to continue, with a convergence of research in all of the relevant sciences. NSF also sees SciSIP as a broad intergovernmental initiative, both within the federal government and internationally.

Gutmann noted that NSF is one of two institutional co-chairs, along with the Department of Energy, of the Interagency Working Group on Science of Science Policy that brings together the best ideas across the government.[11] That working group is just now rolling out an initiative on large-scale data for understanding the science of science policy. NSF looks forward to seeing how that initiative goes forward and to fostering linkages of federal statistical data with research in the underlying social sciences through interagency collaboration.

Gutmann urged the conference participants to think about two fundamental questions. First, how can deeper knowledge of science and innovation policy be translated into better outcomes for the nation? Second, looking in the other direction, what does rapidly advancing knowledge of science policy mean for the evolution of the social and behavioral sciences and their impact on society as a whole?

PERSPECTIVES OF SCIENCE AND INNOVATION POLICY MAKERS

The Roundtable of Science and Innovation Policy Makers was led by Albert Teich, former head of science policy at the AAAS and currently affiliated with the Center for International Science and Technology Policy at George Washington University. In his opening remarks, Teich stated that the purpose of the session was to establish what science policy makers want from the SciSIP program. As important background, in addition to the reports of two workshops of SciSIP grantees cited by Feller above, Teich recommended the foreword by former U.S. Science Advisor Marburger in *The Science of Science Policy—A Handbook* (Husbands Fealing, Lane, Marburger, and Shipp, 2011), together with a chapter in the handbook that was in part inspired by Marburger's charge to researchers—the production of knowledge that improves the management of the science and technology enterprise in the United States.

Teich then introduced the speakers: Sharon Hays, Computer Sciences Corporation and formerly chief of staff at the Office of Science and Technology Policy (OSTP) under Marburger; Thomas Kalil, OSTP; Joel Scheraga, Environmental Protection Agency; and William Colglazier, Department of State. Each speaker addressed the importance of SciSIP research, converging on the same key point—the need for greater and more timely communication of ideas between policy makers and researchers. This necessary bridge-

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[11]The interagency working group is chartered under the SBE subcommittee of the National Science and Technology Council; see http://scienceofsciencepolicy.net/page/about-interagency-working-group-science-science-policy-sosp-iwg [January 2014].

building was described as the creation of infrastructure and incentives that foster meaningful and productive information development and sharing.

Remarks of Sharon Hays, Computer Science Corporation

Sharon Hays reflected on how Marburger's vision and leadership influenced the evolution of the science of science policy, noting two important contributions of his speech to the AAAS in 2005. First was his call for the development of frameworks, tools, and datasets that could form the foundations of evidence-based decision-making in science and innovation policy; second was his call for the coalescence of the discipline of the science of science policy. Hays recalled that "… Jack wrote all of his own speeches, and this one was no different." In Marburger's own words (Marburger, 2005):

> Much of the available literature on science policy is being produced piecemeal by scientists who are experts in their fields, but not necessarily in the methods and literature of the relevant social science disciplines needed to define appropriate data elements and create econometric models that can be useful to policy experts.
>
> I am suggesting that the nascent field of the social science of science policy needs to grow up, and quickly, to provide a basis for understanding the enormously complex dynamic of today's global, technology-based society. We need models that can give us insight into the likely futures of the technical workforce and its response to different possible stimuli. We need models for the impact of globalization on technical work, for the impact of yet further revolutions in information technology on the work of scientists and engineers, for the effect on federal programs of the inexorable proliferation of research centers, institutes, and laboratories and their voracious appetite for federal funds, for the effect of huge fluctuations in state support for public universities. These are not items that you can just go out and buy, because research is necessary even to frame an approach. This is a task for a new interdisciplinary field of quantitative science policy studies.
>
> … but I worry constantly that our tools for making wise decisions, and bringing along the American people and their elected representatives, are not yet sharp enough to manage the complexity of our evolving relationship with the awakening globe. I want to base advocacy on the best science we can muster to map our future in the world.

Hays said she was struck by how Marburger articulated and synthesized the essential elements of an internal policy discussion that he and his staff at OSTP had been engaged in for months prior. The National Institutes of Health budget had almost doubled from its 1997 level, and there was the sense that other disciplines needed attention—specifically, the physical sciences, mathematics, and engineering. However, OSTP asked what evidence could support determining an optimal funding increase for the natural sciences and the optimal portfolio between the biological and medical sciences compared with the physical sciences and engineering. Decisions were mainly based on “go-to anecdotes” about the importance of R&D and serendipitous research findings oftentimes found using Internet searches.

Hayes also drew attention to Marburger’s call for greater engagement, collaboration, and productivity of scholars and practitioners in the social science of science policy, to the point where it could become a discipline. Not only did Marburger want tools at the ready for the decisions at hand, but also he wanted a cadre of experts—policy makers and researchers—who could develop new implementable techniques for informing science and innovation policy. This vision has been interpreted by some as a call for a community of practice that continually develops frameworks, tools, and datasets for implementing science and innovation policy.

Hays ended her remarks with a personal reflection:

> It’s interesting to me that Jack’s speech was shaped largely by what many viewed as a debate in that zero sum game that is the federal budget development process between the biomedical sciences and the other disciplines such as, in particular, the physical sciences. But what arose, interestingly enough, was the flourishing of a set of disciplines that traditionally have not gotten as much attention in these policy debates about the R&D budget: economics, the social sciences, and so forth, which may for all I know may have been one of Jack’s motivations in the speech that he gave.

She went on to encourage the community of practice not only to celebrate what has already been accomplished, but also to continue to develop econometric models and estimates of return on investment to federal investment in scientific research, and to pursue other related questions that have been around for many years.

Remarks of Thomas Kalil, Office of Science and Technology Policy

Thomas Kalil gave his perspective on the importance of the SciSIP program from his role as a member of the White House staff in OSTP, serving as a “policy entrepreneur”—one who develops new ideas and solutions to science and innovation policy issues for consideration by the President and the senior members of the administration, particularly in the run-up to the State of the Union and the preparation of the President’s budget. Kalil impressed on SciSIP researchers that he has seen many occasions in which closer interactions between policy makers and academic researchers could have led to more productive outcomes. Obstacles to such collaborations need to be better understood and overcome. Kalil gave three specific instances to elucidate the importance of two-way communication between SciSIP researchers and policy practitioners.

First, Kalil gave the example of “advanced market commitments,” citing Michael Kremer’s (2001) work on development of vaccines for diseases that disproportionately affect the poor and particularly when markets are imperfect or nonexistent. Without a viable market, profit-maximizing firms are reluctant to develop drugs. The solution, based on Kremer’s findings, allows governments and donors to agree to purchase from pharmaceutical companies a sizable volume of doses of the new vaccine at a stated price. This agreement would require a large enough purchase by the buyers such that the producers of the vaccine would find it economically feasible to finance research, development, and production of the new drug. The risk of making the drug would be mitigated by the agreement, and if the companies were not successful in developing a viable vaccine, then governments would not be responsible for any of the development costs. Kremer called this a “pull mechanism” as opposed to the traditional push mechanisms of funding research and development. Kalil said that a Washington-based think tank, the Center for Global Development, created a task force on the issue in 2003, released a report in April 2005, and saw its concept embraced by the G-7[12] finance ministers in 2006.[13] Five countries and the Gates Foundation together supported one of these ventures in 2007, and by 2010, poor children in developing countries were being vaccinated with a pneumococcal vaccine, which was expected to prevent seven million of these children from dying of diseases such as pneumonia and meningitis over the next 20 years.

Kalil noted further that this idea of pull mechanisms, although initially framed in the context of global health, is now also used in the area of global agriculture. In June 2012, the G-20[14] announced its support for the AgResults Initiative,[15] which is going to use a pull mechanism to stimulate innovation for global food security and agricultural development. The initial impact of the research and positive unintended consequences are what encouraged Kalil to anticipate similar opportunities stemming from the SciSIP research community. He impressed on the audience that “ideas matter, and academics can play a very important role in getting policy makers to consider new approaches.”

For his second example, Kalil cited the work of Harvard University labor economist (and SciSIP principal investigator) Richard Freeman, which illustrates that research can be policy-relevant even when presented in academic forums. Kalil referred to a Hamilton Project paper by Richard Freeman that clearly delineated results of a study on NSF-sponsored graduate research fellowships (Freeman, 2006). White House policy staff found the paper useful because it had a very specific proposal that was perceived as straightforward to implement—namely, according to a bullet point in the abstract of the paper: “The supply of applicants contains enough qualified candidates to allow for a

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[12]The G-7 or Group of 7, is an international group of finance ministers from the following countries: Canada, France, Germany, Italy, Japan, United Kingdom, and the United States.

[13]See http://www.kaiserhealthnews.org/Daily-Reports/2005/December/05/dr00034135.aspx?p=1[January 2014].

[14]The G-20 or Group of 20, is a group of finance ministers and central bank governors from the following countries and region: Argentina, Australia, Brazil, Canada, China, European Union, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, United Kingdom, and United States.

[15]See http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/ORGANIZATION/CFPEXT/0,,contentMDK:23005969~pagePK:64060249~piPK:64060294~theSitePK:299948,00.html [January 2014].

sizeable increase in the number of awards without greatly reducing measured skills." Kalil said that, inspired by the results in the paper, the administration was able, even with budget constraints, to increase the budget enough to raise the number of grants considerably throughout the late 2000s.

The third illustration that Kalil presented was based on the work of Harvard Business School professor Karim Lakhani (e.g., Lakhani and Jeppesen, 2007), who has written extensively on problem solving using open-source networks or "open innovation." NASA found that a solution for getting research-to-policy was to partner with Lakhani, creating a tournament lab, which is allowing NASA rapidly and inexpensively to crowd-source problems that require improved algorithms or software solutions. Kalil indicated that NASA is getting results that have been deemed to be better, faster, and cheaper using open innovation, and Lakhani is getting peer-reviewed publications with novel data from the activity.

Based on the lessons learned from these and other examples, Kalil offered his suggestions on ways to increase the flow of questions that policy makers have to academic researchers and to decrease barriers to the flow of ideas from researchers to policy makers. He stressed they are not one-size-fits-all solutions, but they offer some food for thought that could improve science and innovation policy outcomes:

(1) Policy makers could be more transparent about questions that require formal analysis. There are already processes in place, such as requests for information and notices of inquiry. However, Kalil suggested informal ways of connecting researchers and policy makers could be useful, for instance, following Lakhani's open-source techniques. An example of this would be the use of Internet sites devoted to answering policy questions.

(2) Second, information that policy makers need to know or have at their disposal could be curated to move a given agenda forward. This would increase the extent to which academics not only provide empirical analysis about the status quo, but also offer policy prescriptions about public and private actions that could lead to more desirable outcomes.

(3) Finally, he suggested that NSF has the opportunity to develop specific activities to capitalize on key broader impacts of research that the SciSIP program has supported. For example, the NSF Innovation Corps Teams Program (I-Corps Teams) connects faculty and students that have potentially commercially relevant inventions to entrepreneurs that can help them move these ideas from the laboratory to the marketplace.[16] An analogous set of activities could be put in place that could help researchers with interesting ideas move those ideas from scholarly journals to consideration by policy makers. Another example could be borrowed from the Hamilton Project at the Brookings Institution.[17] Academics would publish an article in a scholarly journal, of which the final paragraph would suggest a given policy that could be implemented based on the findings. To avoid the problem of the policy maker never reading the article or the researcher not knowing enough information to design a useful policy, the activity would arrange for

[16] See http://www.nsf.gov/pubs/2012/nsf12602/nsf12602.htm [January 2014].
[17] See http://www.brookings.edu/about/projects/hamiltonproject [January 2014].

academics who are interested in policy issues to produce 25- to 30-page papers, with 5-page summaries that are configured into a format that maps onto key policy design questions, thereby moving the initial ideas from academic publication to practice.

Kalil finished his remarks by commenting that he was very much interested in staying engaged with the SciSIP community. He said he wants to establish concrete conduits that could strengthen the two-way dialogue and partnership between policy practitioners and the academic research community.

Remarks of Joel Scheraga, U.S. Environmental Protection Agency

Joel Scheraga focused his remarks on the opportunities that are often obscured by the challenges of translating scientific information into timely and useful insights to inform policy and resource management decisions. He said research in the field of science policy is not focused on answering the particular questions being asked by decision makers at a point in time. In addition, even with an appropriate focus, scientists are often hesitant to inform policy decisions because they do not feel the science is “good enough yet” for use by policy makers.

Scheraga challenged the SciSIP community to build “a lasting bridge” that would facilitate information exchange between social scientists, natural scientists, the private sector, and policy makers, with the expectation that the ongoing dialogue and collaboration would yield better outcomes in a more timely fashion. He used illustrations from the environmental policy domain to emphasize how such collaborative efforts have been and could be productive.

Scheraga’s first illustration was of a current federal government partnership with states, tribes, and local communities across the country to enhance the resilience of communities and businesses to climate change. Billions of dollars are being spent now by cities all across the country on costly infrastructure in coastal areas, and much of that infrastructure is vulnerable to sea level rise and storm surges, the frequency of which will go up as the Earth’s climate changes. Decision makers want to ensure that when these investments are made, whether it is by the public sector or the private sector, this costly infrastructure is protected and resilient to more frequent and intense storm events that will occur and are already occurring. Scheraga noted that better decisions could be made if they were informed and supported by the best available science at any particular point in time, including social science.

His second illustration concerned the operations of federal agencies in the face of climate change. In October of 2009, President Obama signed an executive order that called on the Interagency Climate Change Adaptation Task Force[18] to recommend how the policies and practices of federal agencies all across the country could support a national climate change adaptation effort. A year later, the task force provided a set of recommendations to the President, two of which Scheraga highlighted during his remarks.

[18]See http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation [January 2014].

(1) The first recommendation from the task force to the President called on all 63 federal departments and agencies in the federal government to develop and implement climate change adaptation plans with the express goal of ensuring that they could continue to fulfill their missions even as the climate changed.
(2) The second recommendation was to improve the integration of science into decision making. There was a need to prioritize activities that address science gaps important to adaptation decisions and policies being made right now by federal agencies and their partners. It was also important to develop "science translation capacity" to improve the communication and application of science to meet the needs of decision makers.

Scheraga reported that on June 29, 2013, federal agencies including EPA delivered their climate change adaptation plans to the Council on Environmental Quality. The agencies are now beginning the implementation phase. Those involved in the programs face the challenge of needing more information from the research community on which to make decisions. Scheraga indicated that policy makers know where the holes are, and that researchers could provide necessary information at this critical time in the problem-solving process. Building of that bridge is now a major focus of the U.S. Global Change Research Program,[19] a consortium of 13 federal departments and agencies that spend upwards of two billion dollars on global change research; they are increasingly focusing on involvement from the social and behavioral sciences.

Scheraga's final example related to the activities at EPA and other federal agencies that are "passionate" about helping tribes across the country adapt to a changing climate. Particularly, they are working with tribes living in coastal areas of Alaska who are coping with the changing climate. He mentioned the Newtok, Shishmaref, and Kivalina communities, where 20 years ago the physical science clearly indicated that homes were falling into the sea. Scheraga asked the social and behavioral scientists to help identify the problem (in addition to the physical science of climate change) and to provide policy makers with the information that would help mitigate the problem.

In closing, Scheraga reiterated the need for institutions as part of the solution to creating better access and communication between researchers and policy makers. He particularly wanted to see both communities try to address the change to the U.S. economy and livelihoods in the presence of climate change.

Remarks of William Colglazier, U.S. Department of State

William Colglazier, in his role as science and technology advisor at the U.S. State Department, took a broader, international view of the importance for SciSIP researchers to improve the accessibility of their techniques and findings. Based on countless discussions with science advisors around the world, Colglazier stated that the topic of science and technology policy is important to developed and developing countries alike. The topic of most common interest is the impact of science, technology, and innovation on economic development and the future prosperity of a given country.

[19]See http://www.globalchange.gov/ [January 2014].

Colglazier listed the questions he found most pressing for science and technology policy makers around the globe as:

- How can a country improve its capacity in science and technology?
- What is the appropriate share of gross domestic product to spend on science and technology?
- What types of investments in science and technology are critical for economic development?
- Where should government focus its investments in education—kindergarten through high school, baccalaureate, or doctoral levels?
- Where is government most influential in funding research and development? Universities? National laboratories? Collaboration with private-sector firms?
- What policies can encourage bigger linkages between the universities and industries? What types of government programs might be most effective in stimulating academics and others who translate new ideas and inventions into commercial products?
- What are the most effective policies to facilitate startups and entrepreneurs, or to attract venture capital to potentially transformative emerging sectors?

The importance of salient anecdotes and stories was the main thrust of Colglazier's closing remarks. He described three National Academies reports that informed science and innovation policy decisions in recent years, for which the compelling evidence was mainly qualitative. The first report, *Rising to the Challenge: U.S. Innovation Policy for the Global Economy* (National Research Council, 2012b), assessed comparative innovation policy looking at countries around the world. The report was particularly compelling because its recommendations were a consensus of experts from academia, government, and industry. The second report, *Research Universities and the Future of America: Ten Breakthrough Actions Vital to our Nation's Security and Prosperity* (National Research Council, 2012a), looked at what the United States needs to ensure that its research universities stay at the forefront in the 21st century. The last report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter* Future (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2007), had a major influence on the U.S. Congress, inspiring the America COMPETES Act of 2007. All three reports pooled judgments from experts about what the nation should do on these very important issues. Colglazier summarized his point this way: "Even the anecdotes sometimes carry more sway than some of the most carefully done academic research." He suggested that social science and anthropological research have important tools for improving this type of evidence for use in public policy.

Discussion

Following the prepared remarks of the four panelists, Teich asked them a set of questions that have historically been the fodder of discussion, debate, and research regarding science policy: How much? Which fields? Is it possible to answer those questions analytically? And is econometrics, as Marburger would have liked us to think, a good model for science policy? Is it possible to make rationally based policy in a system in the United States in which there are essentially adversarial parts of the government, one of which has hundreds of individual policy makers with their own differing views?

Highlights from the panelists' responses to Teich's questions include:

- There will not be a model that "spits out the right answer to all those difficult questions." However, improvements to the frameworks, metrics, and solution sets for science and innovation policy are possible, and the SciSIP community is expected to produce advances in these areas.
- Metrics should inform the science policy debate, but policy makers should understand their limitations.
- Economics has given policy makers useful rules of thumb regarding investments in science and technology.
- SciSIP research should focus on explaining how ideas move from the laboratory to the marketplace. There is a need for rigorous empirical research to understand why there is a wide range in performance among academic institutions and national labs in technology transfer.
- The question of which fields should be targeted for investment could be better approached by focusing on specific problems to be addressed so that the appropriate array of fields could be drawn in to solve the problem.
- A question is who decides when information is "good enough" to inform decisions. Is it the policy maker (federal, state, or local level), the research scientist (natural scientist, social scientist), or the public? Communication between researchers and policy makers should include discussion on levels of uncertainty that policy makers are willing to accept in the solutions to problems provided by the researchers. It is incumbent on scientists to characterize uncertainties and to communicate the importance of those uncertainties and their implications to policy makers. This may change the way a policy maker implements a policy once the implications of those uncertainties is understood.
- Case studies that are carefully done can be very influential with policy makers. This is particularly evident when implementation strategies for programs are being considered. Having specific examples from previous activities is illuminating to policy makers.
- Congress is a stakeholder in the community of practice discussed earlier. Transparency of process is important—the questions posed, the scientific methods used, information that guided decisions, and so on all need to be communicated to congressional representatives and their staff.

The final question was from an audience member, who wanted the panelists' thoughts on their observation that "there is a fair amount of bipartisan agreement among our parties and members of Congress related to the important of science and technology…" In response, Colglazier recounted a meeting with staff of former Senator Ted Stevens of Alaska on Capitol Hill:

> We discussed this assessment with them [about climate change], and their senior staffer just glazed over. He wasn't interested, he wasn't interested. Just before we left, I was thinking how do I convey to him the importance of this issue, forget the politics? And I finally turned to him and I said: "Do you know what the Alaska pipeline sits on?" And he said "No." And I said "Well, it sits on permafrost. And the permafrost is melting." That's all I had to say. He reached out and asked for a copy of the report.

The capstone observation of the session underscored its main theme. Colglazier stated: "It is incumbent on us to understand the interest and the issues of concern to the stakeholders including up on Capitol Hill, and to communicate in plain English to them the implications of the science for the things that they care about."

3

Project Descriptions: Incentives, Governance, and Innovation

A major theme in the SciSIP-funded research presented at the conference was the nexus of incentives, governance, and innovation. Researchers explored the effects of national and institutional policies, culture, and other influences on rates of innovation in both research and manufacturing.

MANUFACTURING LOCATION DECISIONS AND INNOVATION
Erica Fuchs, Carnegie Mellon University

Erica Fuchs began by noting the significance of SciSIP having funded her work, observing that "it's pretty crazy for an engineer to look at policy problems." The application of engineering models, she added, can help illuminate the relationship between manufacturing and innovation, and she described the way she investigated this relationship. Manufacturing located in the United States accounts for only 21 percent of manufacturing value added in the world as of 2009.[20] That figure has been declining, while the percentages generated in southern and eastern Asian countries are increasing. Increasing numbers of manufacturing firms are "born global," rather than starting out near the source of the innovations on which they rely. In this changing climate, U.S. firms whose manufacturing takes place offshore vary in size and age, in the technologies they use, and in their reasons for choosing an offshore site.

According to Fuchs, data show that for 90 percent of firms the primary reason for choosing offshore manufacturing is to reduce cost, while only 15 percent cite the goal of reaching new markets. There has been relatively little research on the connections between manufacturing locations and product decisions or innovation. Thus, she set out to learn whether manufacturing in an offshore location affects the relative competitiveness of technologies and thereby the technology trajectory of an individual firm or an industry—the types of technologies the firm or industry uses and its willingness to adopt new approaches. She investigated innovation in the automotive, telecommunications, and computing industries to pursue this question.

The existing literature shows vast differences in manufacturing processes around the world, Fuchs observed. There are differences in, for example, yields, downtimes, the quality of materials, and in how production line workers are organized, but these

[20] In the context of economics, a sector's value added is its contribution to the economy, which is calculated as its outputs minus the inputs required to produce them; see http://data.worldbank.org/indicator/NV.IND.MANF.ZS [January 2014].

differences have not been linked to decision making. Because these are precisely the sorts of differences that one would expect to influence manufacturing design decisions, she explored emerging manufacturing technologies in two areas to trace possible connections. Fiber-reinforced polymer composite unibody construction, she explained, offers the automotive industry a potentially perfect substitute for existing technologies, with potential benefits that include lighter vehicle weight, energy savings, and lower fuel costs. Similarly, in the telecommunications and computing industry, the capacity for monolithic integration of multiple functions into a single computer chip, originally developed by small telecom firms, offers the possibility of significantly increasing processing speed and other benefits.

Fuchs examined data from manufacturing shops in the United States and in developing countries in East Asia, and found that in both industries, the site of manufacturing affected the calculation of the relative economic benefits of the prevailing design versus the innovative design. Firms that located their manufacturing in the United States found the emerging design to be more cost-competitive, while those located in East Asian countries found the prevailing design to be more cost-competitive. Through interviews, she found that decision makers at these firms accordingly behave "like rational economic actors," moving operations overseas and using the old technology. This makes sense in the short term, she noted, but if market demand for lighter weight vehicles or greater processing speed increases, these firms may not be well prepared to meet it.

The new computer chip technology, which could be applied in, for example, biosensors that could be placed inside the body or the development of smaller photonics, was affected by the bursting of the "telecom bubble" in 2000, Fuchs explained. By 2003 this technology was producing only 20 percent of the revenue that had been forecast. As a result, the pressure to reduce costs was great even in the top ten firms, which collectively account for 65 percent of the total revenue in this market. As she collected data and interviewed employees, she found the engineers were saying, "We can reduce costs—just give us a little time [to develop monolithic integration]." At the same time, financial managers were focused on reducing labor and packaging costs, and as a result, seven of the eight firms that had been located in the United States moved overseas.

Fuchs's analysis of the outcomes for the firms she studied showed that "even if you are the best in the industry at producing the old technology" in the United States, the new technology yields far better results, even for firms that are just average at using that new technology. Yet using the old technology in an offshore facility is still less expensive. Moreover, it was not possible for firms to use the new leading-edge technology in the offshore locations, which might seem to be the optimal approach. As Fuchs explained, "The engineers were constantly down on the production line trying to figure out why products were not getting out the door." Furthermore, the firms generally could not afford to have more than one facility, so they had to choose between using the old technology in Asia or the new technology in the United States. When firms moved fabrication operations overseas, she added, they generally stopped innovating even in facilities that remained in the United States—this was not the case when only assembly operations were moved overseas.

Automotive firms do not share the constraint on operating in multiple locations, Fuchs explained in answer to participants' questions. In this case, having plants around the world can help firms make use of opportunities in different places to increase product diversity and innovation. Thus, for her, the question of whether governments should provide support to manufacturers to encourage them to keep their plants in the United States is complicated and the answer may vary across types of manufacturing. [21]

THE EFFECTS OF FUNDING POLICIES ON HUMAN STEM CELL SCIENCE
Jason Owen-Smith, University of Michigan

Jason Owen-Smith looked at the effects of funding policies on innovation in the field of human embryonic stem cell research, including pluripotent stem cell technologies.[22] This is an ideal example for exploring the connection between policy and research decisions, he explained, because stem cell research is cutting edge and offers potentially great benefits, but the use of stem cells has been very controversial and highly politicized. Stem cell research has led to path-breaking discoveries, Owen-Smith noted, including the possibility of growing differentiated human tissue, and even new organs. However, the cells are obtained by culturing cells harvested from a human embryo, which results in the death of the embryo. There are differing conceptions of life and when it begins, so some people view this use of embryonic tissue as immoral.

Owen-Smith noted how federal policy on using stem cells from human embryos has swung back and forth over the past couple of decades. A 1995 amendment to an appropriations bill prohibited the use of federal funds for research resulting in the destruction of an embryo, even those left over from fertility treatments. In 1998 privately funded research discovered embryonic stem cells, and in 1999 the Clinton administration approved federally funded research with existing stem cell lines. President George W. Bush implemented a policy in August 2001 that limited the use of federal funds just to existing stem cell lines and not also to new lines that might be developed; his policy also supported research with adult and animal stem cells. Congressional attempts to expand research with embryonic stem cell lines met with presidential vetoes. Meanwhile, some states passed their own laws supporting embryonic stem cell research. President Obama issued an executive order in 2009 that expanded the scope of federal research with new lines of embryonic stem cells.

Owen-Smith and his colleagues explored the effects of these changes in policy on research in the field. They examined recent research using a census of papers published between 1998 and 2010 reporting research that used either human embryonic stem (hES) cells or induced pluripotent stem (iPS) cells, which researchers make by introducing embryonic genes into somatic (adult) cells. They also conducted random and targeted interviews with scientists who have done this type of research and examined research posters presented at conferences in 2010 that addressed this type of research.

This work yielded three primary findings. First, Owen-Smith explained, scientists do pay attention to regulation and the ethical implications of their work. They are eager to have certainty about what is acceptable, and they want easy access to diverse cell lines

[21] For more details on this research, see Fuchs et al. (2011); Fuchs and Kirchain (2010); Yang, Nugent, and Fuchs (2013); and Fuchs (2013).

[22] Stem cells are undifferentiated or “blank” cells found in the human body with the potential to develop into different cell types that carry out different functions.

that are developed in a morally defensible way. Second, iPS cells are not a "magic bullet" for ethical research because the vast majority of researchers who use iPS cells also use hES cells or have been trained by hES researchers. Technical and ethical questions remain. Last, the way in which a policy is implemented matters more than the goals it was intended to achieve. Uncertainty and confusion about what will be acceptable make investigators more conservative in their choice of materials. As a result, few new hES cell lines are in wide use, and there is an increased concentration in the use of particular types of cells. These circumstances also have meant, according to Owen-Smith, that "new people aren't entering the field very much."

Owen-Smith observed that some of the most prestigious universities have been able to pursue alternate sources of funding through collaborations with colleagues in other countries, and a few states have attempted to fill in some of the gaps in federal funding. These initiatives have not been enough to bring stability to the situation, however. He questioned whether it would be desirable for the system to depend so heavily on state and private support.

Owen-Smith closed with a summary of his suggestions for the field:

- Clear, stable, and uniform rules regarding both hES and iPS cell science are necessary for this field to progress.
- Legislation is needed to ensure continuity in funding for hES cell research.
- Support for hES cell research is necessary for the continued development of promising iPS cell science.[23]

ECONOMIC SPILLOVERS FROM SCIENCE

Bruce Weinberg, Ohio State University
Subhra Saha, Cleveland State University

Governments are important supporters of scientific research, observed Bruce Weinberg, and "government activity is increasingly motivated by the economic benefits it is supposed to generate." However, the economic benefits of science are frequently disputed even among scientists, and there are no standard methods for evaluating them. He, Subhra Saha, and Lura Crispin sought to establish a set of methods that could be used to evaluate economic spillovers, and also provide estimates of their value, though he noted that the work is at a preliminary stage.

Science may have a direct economic impact, Weinberg explained, if it pushes the frontiers of knowledge in a way that can be applied in the development of new products, technologies, or treatments. These benefits are important and have received attention in the literature, so Saha and Weinberg focused on indirect benefits beyond those that directly affect workers and firms. These are benefits that spread to local economies. For example, scientific activity may attract a better educated workforce, foster the development of a "hub" for innovation, or lead to ideas that solve industrial problems.

[23]For more details on this research, see: Owen-Smith and McCormick (2006); McCormick, Owen-Smith, and Scott (2009); Scott, McCormick, and Owen-Smith (2009); Christopher, McCormick, and Owen-Smith (2010); Scott et al. (2011); and Owen-Smith, Scott, and McCormick (2012).

Job creation is one potential benefit that gets a lot of attention, Weinberg noted, but he suggested that tracing the links between science and jobs is very difficult. Instead, he and Saha focused on ways in which science may raise the productivity of firms in a particular area. The production of ideas and knowledge is likely to cause firms to expand and hire and to build larger plants and factories. Such activity should, in turn, increase the demand for both labor and land and yield higher wages and real estate prices. However, Weinberg added, such activity might attract a wide range of workers in terms of skill levels, and average wages may not rise even though economic activity is stimulated.

Weinberg also cautioned that the numerous differences among cities make comparisons complicated. The cities in which scientific activity and innovation are prevalent may be different from other cities in certain ways—having higher than average educational attainment levels, for example. Other factors besides the presence of science researchers may make a city an attractive place to live, so a credible estimate of the impact of science must control for those effects. Thus, Weinberg and Saha’s project began with an analysis of longitudinal data on metropolitan areas to establish basic differences among cities, and census data to establish and control for worker characteristics. The researchers used data on science funding collected by the National Science Foundation, information on patent applications from the U.S. Patent and Trademark Office, and other data to assess scientific activity. They focused on cities that are home to institutions that receive large amounts of funding for research.

The researchers used an economic cost function productivity model to estimate the benefits of scientific activity. Their results suggest that the presence of scientific activity is associated with higher wages in cities; the data are not sufficiently clear to support conclusions about the effect on real estate prices. The researchers intend to explore the specific influence of the patenting of scientific discoveries, which may have the largest economic effects, as well as the preliminary finding that local spillovers from science are increasing over time.

Weinberg noted that the magnitude of the benefits of scientific activity is large, though he acknowledged that the estimates are “a little bit fuzzy.” He suggested that increasing science spending by, for example, $1 billion over a year or two across the nation could increase wages and real estate prices by slightly more than one-quarter of 1 percent. “That does not sound very large,” he noted, “but if you use conventional estimates of the share of labor and real estate in the economy, you wind up with an increase in productivity of just under one-fifth of a percent.” The return would be greater the longer the science spending were sustained, he noted, but “certainly this would seem like a nice return.”

THE IMPACT OF OPEN-ACCESS INSTITUTIONS AND POLICY ON LIFE SCIENCES RESEARCH

Scott Stern, Massachusetts Institute of Technology

Scott Stern described a systematic research program aimed at establishing not just correlations between policies or institutions and positive outcomes for science, but actual causal linkages between open access and particular sorts of scientific progress. He pointed to Isaac Newton’s observation that each generation stands on the shoulders of giants, and explained that he and his colleagues hoped to shed light on how knowledge is actually transferred. "Simply producing knowledge does not at all guarantee its accessibility," he noted. "Knowledge transfer by its very nature is very costly," he added, and "knowledge … can be maintained as a secret … in a way that makes it difficult to facilitate follow-on research across research generations."

Specifically, Stern and his colleagues wondered how open-access institutions (those that require their researchers to make their published results freely available to others) and policies that support a "scientific commons" approach to science contribute to the accumulation of knowledge and research productivity. They hoped to learn what conditions give researchers and research funders incentives to contribute to open access, and what roles institutions and public policy play in fostering those conditions.

Stern first described his and his colleagues' findings with respect to biological resource centers, though the project has covered other areas as well, including mouse genetics and the Human Genome Project. Biological resource centers are places that store large stocks of specialized cell lines that are made available to scientists. These include stem cells as well as many other types of cell lines. Biological resource centers have many advantages: They provide independent access to the material they hold so researchers need not compete for it, and they can preserve material for a long time—potentially longer than any individual researcher would be able to. These centers also authenticate the material so that those who use it can be confident in its source, an issue that has presented problems in the past.

To establish the outcomes of making particular biological material accessible, Stern and his colleagues traced the pattern of publications on related topics before and after the material was made available, and also compared those rates to control rates for other areas where there had not been a comparable sharing of research material. Whenever material is deposited in a resource center for whatever reason, it is linked to a particular citation, which will then be included in any future work with that material. Particularly beneficial for the before-and-after comparison were cases where the material was deposited in a resource center many years after the discovery had first been made and published.

Stern and his colleagues found "a relatively big effect" of opening access to these cell lines, he explained: a doubling in the rate of citation of the articles linked to open-access cell lines, compared with the controls. Moreover, the citation rates increase over time. "The biggest effect is associated with the number of institutions that cite an article, the range of journals that cite the article, and the geographic reach of the citations," Stern noted. They found similar results when they examined mice bred for scientific research, some of which have been patented. When particular mice are made available through open-access programs, he explained, there is a large increase not only in the number of authors and institutions involved in related research, but also in the diversity of research topics being pursued using the mice.

"Scientists by and large want to do the right thing," Stern concluded, but it is important to understand what motivates them as they make decisions, and what characteristics of the research environment "make it easy for them to do the right thing." Researchers who might pursue more speculative kinds of work that could build on what has already been done, he explained, are encouraged and supported when there are formal institutions and policies that "provide independent, low-cost access to tools, databases, materials, and even pieces of intellectual property."

COMMUNICATION, COLLABORATION, AND COMPETITION
Jerry Thursby, Georgia Institute of Technology

The ways in which scientists decide to share their work with colleagues and the factors that influence these decisions was the focus of work by Jerry Thursby and his colleagues. In a prior study, they had explored what they call "specific sharing," in which a scientist "makes a specific request to another scientist for materials, for an algorithm, or data." They found that the tradeoffs and incentives in these situations are very different from those that influence decisions about public presentations of intermediate results, which they call "general sharing." They decided to follow up with a closer look at general sharing.

The researchers began with three models of how sharing might be viewed, which are based on game theory (the study of strategic decision making in conflict situations). The *competition/collaboration model* describes the calculation that disclosure could lead either to competition from other researchers that is undesirable (because a competitor might beat the original researcher to a solution or breakthrough), or to productive collaboration. The *mathematician model* describes a situation in which competition is desirable because no one can receive credit for a discovery until the work is completed. For example, a mathematician might have a theorem that has largely been proven, but be unable to complete the last portion of the proof. The mathematician might share it in order to create interest, in hopes that another mathematician will solve the last portion. The *research leader model* describes a situation in which the reputation of a researcher is enhanced if his or her work inspires others to work in the same area, thus demonstrating the powerful influence of the original work.

In considering the competition/collaboration model, Thursby went on, it is important to distinguish among types of researchers who may behave differently. The focal researcher—the decision maker—has made a discovery that is of partial value in solving a problem. That person will have to decide whether to share results with colleagues in the field, who are either close colleagues who can be trusted not to compete, or general colleagues who might decide to compete. The main potential benefits to sharing are gaining credit in the field for the initial discovery and possibly finding a collaborator. The risk is that a rival with better resources or skills will engage in the research and outpace the focal researcher.

Thursby and his colleagues developed simulation models to explore the results for each of the three models for how sharing might be weighed. They assigned values to each of the factors that would influence the outcome of sharing or not sharing with the two types of colleagues. The factors include the relative ability of the researchers involved, time saved if two able researchers collaborate, the opportunity cost of not working on some other research, and the like. The results varied across the three sharing models. In the competition/collaboration model, researchers are much more likely to share incremental work than breakthrough discoveries, while the opposite is true in the mathematician model. In the research leader model, the outcomes depend on the relative capability of the researchers involved.

The next step will be to survey approximately 60,000 U.S. researchers and 20,000 German researchers, and to interview a subset of this group, to collect data on their decisions about what they disclose, the point in their research at which they disclose, and the reasons for their decisions.[24]

GENERIC DRUGS AND INCENTIVES FOR RESEARCH AND DEVELOPMENT

Matthew Higgins, Georgia Institute of Technology

There has been an exponential increase in spending on research and development (R&D) in the pharmaceutical field during the past few decades, noted Matthew Higgins, but the approval of new products has remained constant or lagged behind these expenditures. Anecdotal evidence, he added, suggests that pharmaceutical firms have moved away from developing certain kinds of drugs partly in response to competition from generics. While it is likely that a combination of factors are affecting this industry, Higgins and his colleagues explored the possibility that regulation policies that speeded approvals for generic drugs may partially account for the discrepancy.

Current regulations for new drugs are laid out in the Drug Price Competition and Patent Term Restoration Act of 1984, P.L. 98-417, also known as the Hatch-Waxman Act. The law provides patent and other protections for new drugs, and when these protections expire, other manufacturers can file a request to sell the product as a generic drug. In some situations, manufacturers can use legal challenges to get earlier access to new drugs. The law covers only chemical-based or small-molecule drugs, Higgins noted, not biological drugs. Current law governing biologics allows them 12 years of market exclusivity and makes no provision for allowing manufacturers of generics into the market.

Higgins noted that the current regulations for chemical-based drugs have created a situation in which drug developers have a very short time to reap a return on their investment, because once generics enter the market, their revenue declines very rapidly. This is not the case for biological drugs because there are no “biosimilars,” drugs that can mimic exactly the properties of the original ones. The competition for these drugs is newly developed biologics, rather than generic versions of the same ones.

Higgins and his colleagues investigated three “seemingly simple questions.” The first was whether allowing generic drugs to enter markets earlier than they had been previously was welfare-enhancing (beneficial overall in terms of the ratio between gains and losses). The second question was whether early market entry for generic drugs has reduced incentives for innovation in pharmaceutical research in particular markets. The answers to these two questions provide the backdrop for exploration of the somewhat broader question of whether the result of current drug approval policies is that the United States is sacrificing future innovation for the sake of access to inexpensive drugs today.

The findings are complex. For example, as Higgins noted, the impact of a new generic drug depends on the nature of the drug and the condition for which it might be used. With some conditions, such as epilepsy, insurance companies will not require

[24]For more details on this research, see Haeussler et al. (2013).

patients to switch to an available generic, and doctors may prefer to stay with a drug that is effective. In other cases, the availability of generics reduces prices and provides patients and doctors with more choices. The analysis Higgins and his colleagues conducted took numerous factors into account and showed that, overall, the gains to consumers have been greater than the losses to producers in the current market place. However, they also found that the entry of a generic drug leads to “about an 8 percent decrease in innovation,” with the effect apparently being greater on later stage innovation than on early-stage innovation. Early-stage innovation is also boosted when there are “technological opportunities,” Higgins added, which are promising possibilities identified through basic science research.

There is some indication that current policies have pushed companies to focus more resources on biologic drugs than chemical ones, Higgins observed, and he closed with the observation that both push and pull mechanisms influence the drug market. He suggested that it would be beneficial to have more preventive and curative drugs and that possibly shifts in the regulatory structure would improve the incentives for drug companies to develop the drugs that are most needed. Funding for basic science research might also be used as a mechanism to “push” the industry to develop drugs that are particularly needed. [25]

PATENT RIGHTS IN THE SOVIET UNION
Lisa Cook, Michigan State University

Lisa Cook set out to learn whether patent rights are necessary to spur robust innovation. It is difficult to study this question in a market economy, she noted, but socialist countries provide an “interesting laboratory” because they traditionally have not extended patent rights to their citizens.[26] She noted that there was a slowdown in technological advancement in the Soviet Union during the 1970s that caused policy makers significant concern. In response, she explained, planners developed incentives to encourage individual inventors. Until now it has not been possible to test whether these incentives worked, but newly available archival data make it possible to assess the contributions of Soviet inventors during this period.

In general, Cook explained, the Soviet Union provided recognition to inventors in the form of inventor’s certificates, but the certificates did not designate anyone as the original inventor of anything or give the recipient any control over the invention. Technically, inventors could apply for patents, but most were granted to foreigners—just 0.01 percent of patents granted between 1973 and 1991 were issued to Soviet residents.

The market-like incentives that were introduced, Cook noted, included increased compensation and tax advantages for individual inventors, as well as such non-pecuniary benefits as housing privileges, promotions, and prizes. Authorities also instituted a requirement that inventors at research institutes produce innovations of national or international significance, although the significance of this was difficult to measure. An entity called Licensintorg was established in 1962 to facilitate the licensing and

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[25]For more details on this research, see Branstetter, Chatterjee, and Higgins (2013a and 2013b).

[26]Cook noted that her work builds on previous work by Moser (2004, 2005); Brunt, Lerner, and Nicholas (2012); and Moser and Rhode (2011).

marketing of Soviet inventions abroad, Cook noted. By 1962, 62 licensing agreements had been negotiated with the United States and other countries.

Further changes included a 1979 reform of research and development designed to encourage individual investors, and patent reform carried out as part of perestroika. This reform provided limited rights for inventors and promoted research and development in civilian areas, rather than defense. Cook noted that these measures reflected conflicting objectives in the Soviet Union: despite reasons for maintaining secrecy during the Cold War years, the leadership was eager to demonstrate the country's technological prowess.

To assess the outcomes of these efforts, Cook used data from several sources. Files of the United States Patent and Trademark Office and the National Bureau of Economic Research allowed her to trace patents granted to Soviet inventors between 1959 and 1991 (at least one of the inventors was a resident of the Soviet Union or Russia). The patent offices of Russia and Germany were a source for inventor's certificates and patents issued by the Soviet Union.

Cook used a statistical model to examine the effects of the policies on the share of patents assigned to individuals. She noted that if the market incentives were effective, one would expect to see greater patent activity in response to a rise in Gross National Product, and that was in fact evident. She highlighted several additional findings. "Soviet inventors were inventing like crazy outside the Soviet Union," she observed. They obtained many patents from other countries, and their output was comparable to that of medium-sized industrial countries such as Austria, Australia, and Belgium. In general, she concluded, the incentives did have the effect of stimulating inventions. This finding is important, she added in response to a question, because developing countries and others that lack robust intellectual property rights are interested in technological and economic growth and in ways to provide incentives for innovation. She noted that there are follow-up questions to be explored, such as what other factors influenced individual inventors, what other factors affected technological spillovers among countries, and how inventors responded to the fall of the Soviet Union. In another paper, Cook and Ivanya (2012) explored the extent and quality of technological spillovers from these Soviet inventors. In particular, they examined the effect of the boycott of the Moscow Summer Olympics on these Soviet inventors, which led to a decline in their patent activity in the U.S., and found that there was a significant subsequent effect on Soviet inventors' patent activity in East Germany.

CULTURE AND NATIONAL INNOVATION RATES

Mark Zachary Taylor, Georgia Institute of Technology

Policies and institutions have a significant influence on a nation's relative success in science and technology, noted Mark Taylor, but "they only explain anywhere from half to 75 percent of the story." There are well-designed policies and institutions that have limited effects in some countries, as well as countries that have success in science and technology despite poor policies. Taylor attempted to understand the unexplained differences by trying to determine whether national culture affects rates of innovation. He noted that anthropologists and sociologists do not agree on the definition of culture, and that culture can be viewed as a spectrum that encompasses a very wide range of values, even within a country. Nevertheless, a notion of culture as “a country’s ‘central tendencies’ in terms of values, beliefs, and preferences” has value, he explained. Despite significant variation within cultures, nations do tend to have what he described as “national cultural values,” such as individualism, collectivism, or social or intellectual autonomy, to different degrees.

Discussions of culture may reflect biases, Taylor explained, but social scientists have attempted to quantify the cultural values that tend to be associated with national cultures. Researchers[27] have used survey instruments in numerous countries to establish cultural values by asking large numbers of people about their attitudes and preferences regarding personal traits and values. Looking across this body of work, he added, one can “triangulate”: “If there is some objective thing out there that multiple scientists are trying to measure independently using different methodologies, then the noise should cancel out and the signal should come through.” There are also multiple, independent measures of innovation rates, so, collectively, these data support conclusions about the relationships between the two, in Taylor’s view.

Taylor described several findings. First, individualism as a cultural value seems to correlate strongly with national innovation rates, regardless of how either is measured. This finding held when other possible factors, such as level of development, trade openness, military and education spending, and research and development spending, are controlled. An interesting difference between two different types of collectivism was also evident, Taylor added. In-group collectivism—strong identification with friends, family. or tribe—has a negative correlation with national innovation rates, whereas institutional collectivism—such as patriotism or loyalty to institutions—has a positive correlation with innovation rates. Taylor cautioned, however, that qualitative research is needed to illuminate the causal mechanisms and confirm or disconfirm the picture evident in the aggregate statistics. Participants followed up on this point, noting that historical factors such as immigration might also play key roles but are not captured in the data Taylor described.

The findings do suggest, Taylor noted, that it is important to be skeptical of stereotypes, such as the idea that cultures that value collectivism must therefore be unfavorable for innovation. The findings also suggest that particular policies may work better in one culture than another because of “cultural fit.” He suggested some tentative points related to cultural fit. For example, free markets, democratic systems, and political decentralization may all be more important to innovation in individualistic societies than in collectivist ones. The primary conclusion he reached was that there is strong evidence—stronger than the case studies on which scholars have tended to rely—that culture influences innovation in significant ways. This is important, he noted in closing, because policy makers and businesses would do well to consider culture when designing policies and institutions.[28]

[27]Taylor mentioned Geert Hofstede, Shalom Schwartz, Robert House, Fons Trompenaars, Charles Hampden-Turner, and Ronald Inglehart as researchers who have done this work.

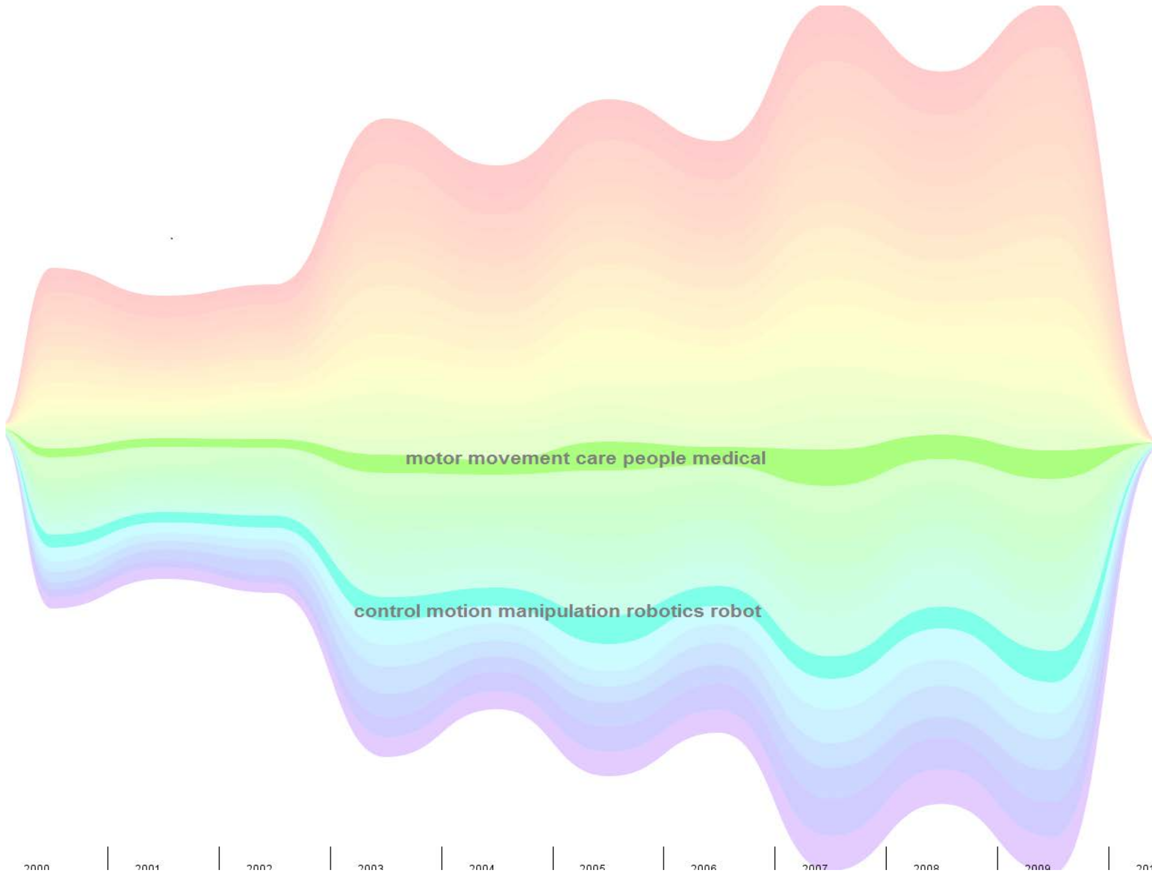
[28]For more details on this research, see Taylor and Wilson (2012).

IMPACT OF SCIENCE FUNDING
William Ribarsky, University of North Carolina at Charlotte

William Ribarsky, Wenwen Dou, and colleagues demonstrated digital tools for examining the relationship between science funding and the evolution of research fields. These tools use what they describe as a visual analytics approach. The tools make it possible to trace the progression of activity in a particular area. With these tools, Ribarsky explained, it is possible to analyze empirically and then represent visually the prevalence of particular ideas in proposals, papers, and the broader media. The visual representations can reveal trends, the impact of events or relationships, and the possible cause and effect relationships. The tools (ParallelTopics and LeadLine were primary examples) can be used for general exploration and to identify general trends or to conduct more detailed analyses. They can be used to forecast future impacts or to support decision making, he observed.

The visual representation tools make it possible to trace and depict the prevalence or impact of particular ideas, beginning with their presence in funding proposals (such as to the National Science Foundation) through the publication of papers and the granting of patents. Ribarsky and his colleagues have amassed data on 5 million patent applications, for example, and also have folded in textual analysis of papers and such other sorts of data as online news sources, technical and business blogs, and the like to identify research trends and their impact. Using these tools, Ribarsky noted, it is possible to answer such questions as whether funding is lagging behind research in a particular area, how relationships between funding and research evolve over time, and which proposals and papers are shaping funding decisions. Such answers can be useful in decisions about investments in research and programs or the structure of review panels, Ribarsky concluded.

An example of the information that visual representation tools can encapsulate and summarize is provided in Figure 3-1.



2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

FIGURE 3-1 ParallelTopics visualization: Overview of awarded proposals in NSF Information and Intelligent Systems Division from 2000 to 2010.
SOURCE: Presentation to SciSIP Principal Investigators' Conference by William Ribarsky, 2012.

This ParallelTopics visualization traces trends in proposals awarded by the NSF Information and Intelligent Systems Division in the Computer and Information Science and Engineering Directorate from 2000 to 2010. The data shown include about 4,000 awarded proposals. Each of the color-coded streamlets in Figure 3-1 represents a topic, which is identified by an automatically generated string of keywords. For example, consider the topic “robotics” indicated in light blue and the topic “using interfaces to help people with impairment” shown in green. The two topics selected are labeled with their leading keywords, but all the topics have a set of keywords (indicated by the other colors in the diagram). Selection of a topic at a specified time range gives the proposals’ abstracts for that topic awarded during that time range; a proposal can have more than one topic. The visual representations in the diagram show both the main themes of proposals over time and the programs from which they come. The width of a streamlet scales as the number of award abstracts for that topic at that time. The results in Figure 3-1 show a large jump in the number of awards that is visible in 2003–2004 and again in

2006-2007. Robotics maintained its numbers, while interfaces for people with impairments grew. These and other trends depicted were confirmed through evaluations by a former program manager for the directorate.[29]

VENTURE PHILANTHROPY

Maryann Feldman, University of North Carolina at Chapel Hill

Private foundations play a key role in funding academic research, and Maryann Feldman's research explored how attributes of philanthropic organizations affect the conduct of university research, their relationship to other funding sources and to commercial outcomes of scientific research, and possibilities for a new model of strategic foundation funding of research. She and her colleagues reviewed data on 19,000 projects that received foundation funding between 2000 and 2012. These projects were conducted by 6,000 principal investigators, who received more than $3.2 trillion in funding. Grant proposals provided information about agreements, contractual terms, and principal investigator characteristics, Feldman explained, and other sources provided data about corporate and foundation giving and about technology transfer. Overall, philanthropic funding for research increased during this period.

Approximately 60 percent of academic research and development funding comes from the federal government, Feldman noted, and 8 percent comes from philanthropy. However, internal university research grants, which account for another 20 percent, are also often the product of foundation gifts. Many foundations have adopted innovative funding models because they hope to improve the impact of their gifts, Feldman explained. One such innovation is venture philanthropy, a model in which funders adapt the approaches of venture capitalists in identifying ideas that have commercial potential and using their investments to nurture them and guide their development. For example, a foundation may manage the pipeline of a new drug from the research stage to production for the open market. Typically, a foundation will accomplish this by building a team focused on a particular goal, identifying progress milestones in advance, and assembling a portfolio of work.

There are several advantages to this approach, Feldman observed. Projects funded in this way are often more efficient than others, and funding can directly target areas for which there have been funding gaps, such as riskier research or that being conducted by younger researchers. Faculty members seem to favor this approach, Feldman noted, but the approach is not financially advantageous for universities, which may lose both licensing revenue and overhead payments. Feldman also noted that, in this approach, a small group of funders may dictate research priorities that may not align with the ideas of the research community or the needs of the general public.[30]

[29] For more details on this research, see Dou et al. (2011); and Dou et al. (2012).
[30] For more details on this research, see Feldman and Graddy-Reed (2013, forthcoming).

EVIDENCE ON PATENT POOLS UNDER THE NEW DEAL
Ryan Lampe, DePaul University

As described by Ryan Lampe, patent pools are agreements among patent holders to combine related patents and possibly license them to third parties. For example, the holders of patents on airplane wings and propellers, respectively, might agree to join forces so that airplanes can be developed more efficiently and profitably. Such agreements reduce the risk of litigation among patent holders and may also reduce licensing fees. On the other hand, a pool member may share the benefits of another's invention without making a contribution to the effort. The need to share profits may also reduce pool members' motivation, Lampe added.

Lampe and co-author Petra Moser had noted that a nineteenth-century pool agreement concerning sewing machine technology had the effect of reducing patent grants, and also innovation, as measured by sewing machine speed. To gain a broader picture of the influence of pooling on innovation, they studied patent pools in 20 industries that were affected by the New Deal legislation of the 1930s. Under the New Deal, Lampe explained, there was a window of time in which regulations affecting patents were relaxed, and he and Moser wanted to know whether permissive policies regarding patent pooling had encouraged or discouraged innovation. Twenty pools formed between 1930 and 1938 concerning technology used for diverse applications, including railroad springs, furniture slip covers, and aircraft instruments. Lampe and Moser compared patents granted for pooled technologies with those granted for non-pooled developments in related technologies. They used court records and license agreements held in archives to research a total of 75,396 patents issued from 1921 to 1948. They identified subclasses of patent pools by pool size, technology type, and other factors to explore the reasons for pooling and the outcomes.

Lampe shared several findings. In general, patent rates declined after a pool was created. For example, the existence of a pool delayed the switch from black-and-white film to color film. The presence of a pool arrangement reduced competition among researchers in the pool to develop improved substitutes for existing technologies. In the absence of the antitrust regulations that were relaxed under the New Deal, pools also discouraged innovation by weakening competition in general, he concluded.

EFFECTS OF CHANGES IN FEDERAL FUNDING ON THE BIOMEDICAL SCIENCES
Meg Blume-Kohout, New Mexico Consortium
Krishna Kumar and Neeraj Sood, RAND Corporation

Meg Blume-Kohout and her colleagues used econometric analyses to explore the effects of federal funding for research and development (R&D) on non-federal investment in life sciences R&D at U.S. universities. They took advantage of a change in budget policies at NIH, which resulted in a significant tightening of research funding after 2006, to compare outcomes under different funding regimes. They used multiple longitudinal data sources, including the NSF Survey of Research and Development Expenditures at Universities and Colleges, NIH administrative records, Congressional budget appropriations by NIH Institute and Center, and Congressional subcommittee membership.

Blume-Kohout and her colleagues found that before the reduction in funding, “each federal dollar U.S. universities received spurred an additional $0.25 in research funding from non-federal sources,” including industry, state and local governments, philanthropic donors and nonprofit organizations, and other institutional sources. However, the more competitive funding environment from 2006 onwards had significant impact on less research-intensive universities, Blume-Kohout explained. Like the larger, more research-intensive PhD-granting institutions, these less research-intensive institutions benefitted from dramatic increases in federal funding from FY1998 through FY2004, but from FY2005 onwards, less research-intensive institutions experienced a much steeper decline in federal funds. Nonetheless, when these latter institutions did succeed in attracting federal funds post-2006, their complementary non-federal R&D investment increased by over $0.63 the following year. In contrast, more research-intensive PhD-granting universities appear to have substituted non-federal R&D funding at least 1:1 when federal funding availability declined (see Figure 3-2).

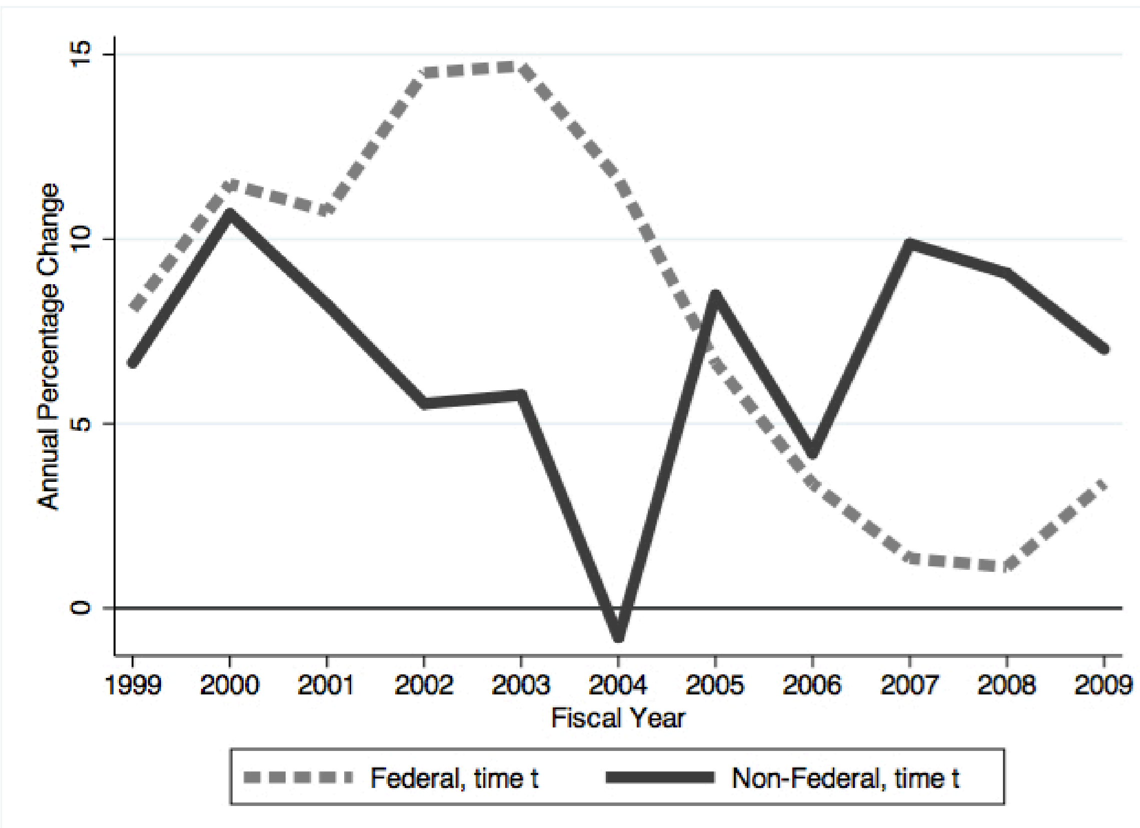


FIGURE 3-2 Non-federal life sciences R&D funding substitutes for federal dollars at Carnegie doctoral high /very high research universities.
SOURCE: Presentation to SciSIP Principal Investigators’ Conference by Meg Blume-Kohout, 2012.

The nonlinearity in non-federal R&D investment responses to the changing fiscal environment could reflect several possible influences. For example, the strong and continuing positive impact of federal R&D funds at historically less research-intensive institutions may be due to signaling effects, or due to a unique role in federal R&D funding in building those universities' productive capacity, particularly via investments in facilities, equipment, or human capital. On the other hand, more research-intensive institutions may make strategic decisions to pursue non-federal funding when federal award success rates and total funding decline.

EXTRACTING AND ASSESSING THE PUBLIC VALUES OF SCIENCE AND INNOVATION POLICIES

Daniel Sarewitz, Arizona State University

Science and innovation policy can have powerful impacts on individuals and society, and Daniel Sarewitz explored ways to understand and measure this impact. He noted that it is important to ask, with respect to any project, what public values it might serve, whether the reasoning about how it might serve those goals is sound, whether the necessary human and institutional resources are in place, and what strategies the project leaders have for linking the institutions and people involved.

Sarewitz explained that by public values, he means desired social outcomes that would justify public investment in particular research. Examples, he noted, include increasing the length and quality of people's lives and eliminating health disparities, ensuring a safe and affordable food supply, and fostering a reliable energy system that is environmentally and economically sustainable. Scientists' perspectives on issues are often different from those of the general public, however, as he illustrated in Figure 3-3, which compares scientists' perceptions of various risks with those of the general public.

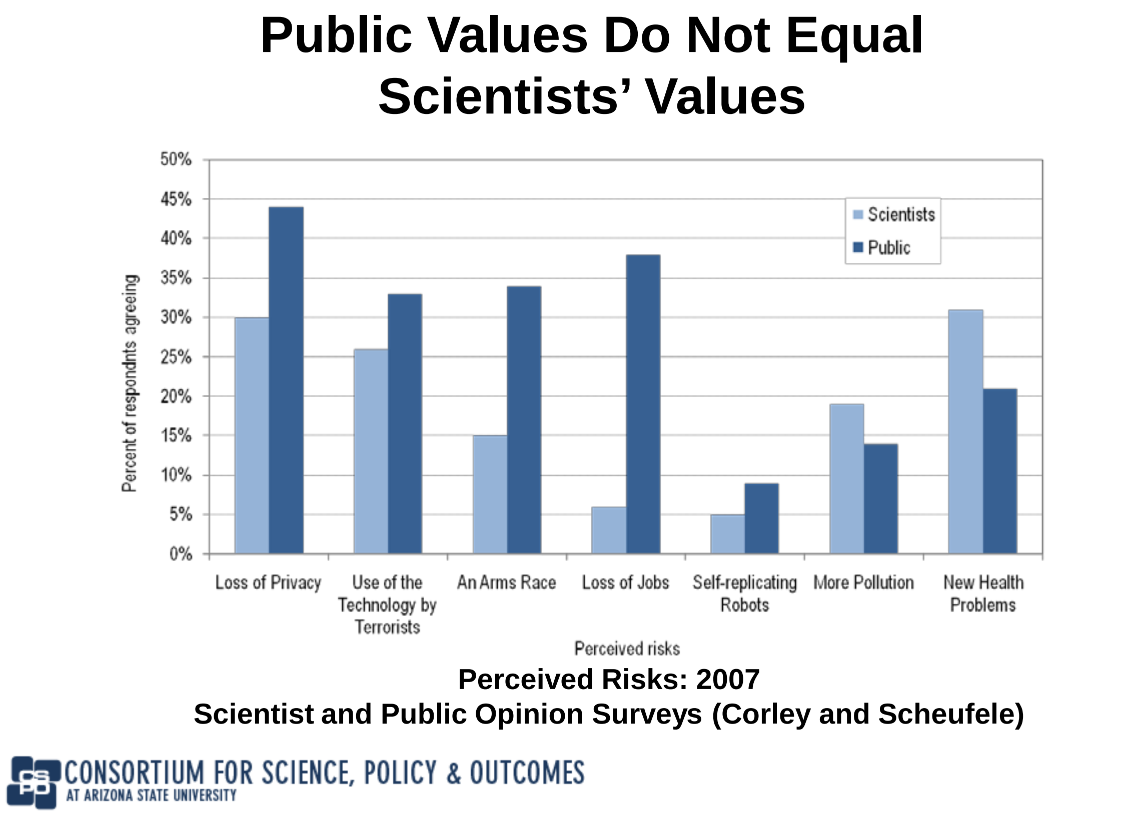


FIGURE 3-3 Public versus scientists' values on perceived risks.
SOURCE: Presentation to SciSIP Principal Investigators' Conference by Daniel Sarewitz, 2012.

Sarewitz noted that the traditional model by which the logic of science policy is mapped does not capture public values well. Figure 3-4 compares the traditional model to the model that he proposes. His model includes a non-economic analysis of public values and the potential impact of a policy on them. Sarewitz noted that there are a variety of ways that science policy may fail the general public. A policy might focus on effects likely within a short time frame in a case where understanding of longer-term outcomes would likely point to a different course of action. Research and development associated with energy is an example: immediate needs for affordable sources of energy may obscure appreciation for the long-term downsides of particular approaches. Figure 3-5 shows Sarewitz's listing of possible policy failures.

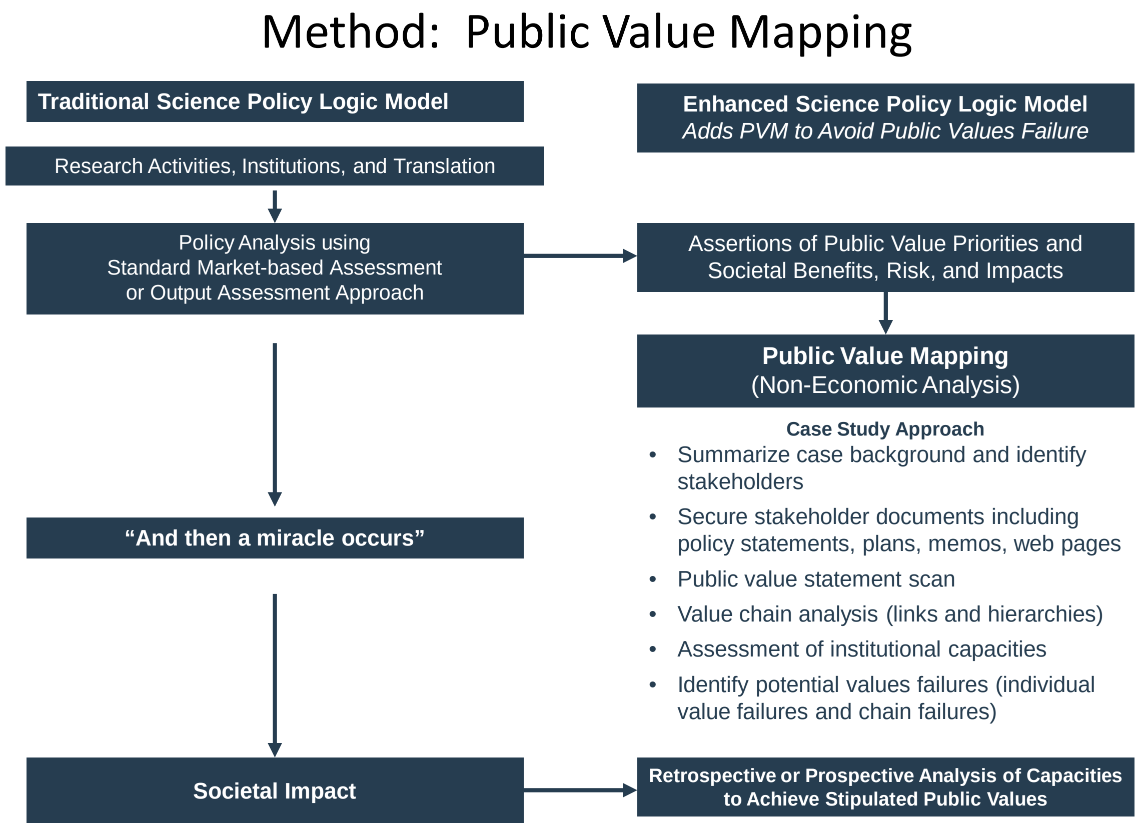


FIGURE 3-4 Traditional versus enhanced science policy logic models.
SOURCE: Presentation to SciSIP Principal Investigators' Conference by Daniel Sarewitz, 2012.

Sarewitz used climate change research to illustrate this point, noting that criteria 1 and 3 in his map apply to failures in this area. Policy in this area has lacked a mechanism for articulating and aggregating public values (criterion 1), he stated. The criteria for assigning priorities to different values are too broad or vague, and the connections between priorities and values or outcomes have not been established. An additional problem is that the stakeholders in climate change science policy are not clearly defined. There is also a scarcity of providers of expertise (criterion 3), he added. Despite recognized needs that lie outside of natural science, priorities have tended to be driven by research in the natural sciences, rather than social science research that might more readily reveal competing values.

Sarewitz concluded by emphasizing that science and innovation policy can have significant impact on people's lives, and that the Public Value Mapping tool can assist researchers, funders, and policy makers in making optimal use of investments in science and innovation.[31]

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[31]For more details on this research, see Bozeman and Sarewitz (2011, 2005); and Sarewitz (2007).

Public Value Mapping: Public Failure Criteria

Public Failure Criterion	Failure Definition	Example
1. Mechanism for values articulation and aggregation	Political process and social cohesion insufficient	Peer review
2. Imperfect monopolies	Private provision permitted yet government monopoly in the public interest	Clinical trials
3. Scarcity of providers	Recognition of public value and agreement on public provision but unavailability of providers	Landsat
4. Short time horizons	Longer term view shows short term actions counter to public value	Energy R&D
5. Substitutability vs. conservation of resources	No satisfactory substitute	Wetlands protection or sale of human organs
6. Benefit hoarding	Commodities or service captured, limiting distribution to the population	Terminator gene

FIGURE 3-5 Listing of public failure criteria.
SOURCE: Presentation to SciSIP Policy Investigators' Conference by Daniel Sarewitz, 2012.

4

Project Descriptions: Work and Collaboration

A number of SciSIP researchers have explored the ways in which scientists work and collaborate and the influences that shape their work and their careers. These researchers have brought the tools and perspectives of various disciplines to bear in analyses of team functioning, scientific creativity, the experience of Native American researchers, and other related topics.

SOCIAL AND COGNITIVE PROCESSES IN TEAM INNOVATION
Susannah Paletz, University of Pittsburgh

Susanna Paletz observed that most science and engineering innovation is the result of team collaborations. Nine of the top 10 scientific discoveries highlighted by *Time Magazine* between 2007 and 2010 were made by teams, not individuals, she pointed out, adding that "you basically can't do scientific discovery alone at this point." One reason for this is the importance of collaboration among specialists from different disciplines, who ordinarily do not publish in the same journals or attend the same conferences. Many government agencies recognize the importance of cross-disciplinary work, she noted. In the wake of the BP oil spill, for example, engineers, microbiologists, economists, and even social workers needed to collaborate to try to manage all aspects of the damage that was caused.

The diversity of knowledge a team can bring to a task is widely regarded as having great potential for innovation, but, according to Paletz, research on clear connections between diversity and team performance has been weak and has produced inconsistent findings. Simply putting a multidisciplinary team together is not sufficient, she observed, because "sometimes they succeed and sometimes they fail spectacularly." One of the problems with the existing research is that it focuses on the input variable (disciplinary diversity) and the outputs (e.g., publications, supervisor ratings, solutions to problems), without examining the processes by which outcomes are produced by teams. The research that has examined processes has relied primarily on self-reports from team members. There are numerous mediators and moderators, however, that influence what teams produce, Paletz noted, adding that "we don't really understand what the teams are actually doing."

Paletz and her colleagues developed a theory to describe the functioning of team structures, social processes, and cognitive processes, and to account for team innovative divergent and convergent outcomes (Paletz and Schunn, 2010). She described research they have done to explore the elements of their theoretical structure. For example, they addressed the role of uncertainty and analogy, which she defined as transferring information from a domain one knows to another domain in which there is a problem one wants to solve (Chan, Paletz, and Schunn, 2012). Someone who wants to design a tube that can transport liquid but does not know much about possible materials to use might think about strong but flexible materials used in other contexts (e.g., Christensen and Schunn, 2007). Analogous ideas might come from within the same general domain or a completely different one, such as when materials engineers studied the way geckos' feet allow them to adhere to vertical surfaces and adapted the mechanism to develop new adhesives. Thus, teams with members with diverse training and experiences will collectively have deeper and broader knowledge structures to rely on, Paletz explained, and thus likely be more successful problem solvers.

Paletz and her colleagues explored these processes using records of informal problem-solving conversations that took place among the more than 100 scientists who collaborated on the NASA Rover mission. The researchers coded the conversations using social and cognitive variables at the utterance, or clause level. In one analysis, they established the degree of uncertainty the speakers expressed before, during, and after considering an analogy as they solved a problem. The researchers found that the introduction of a problem-solving analogy tended to reduce uncertainty (Chan et al., 2012).

They also examined the different sorts of conflicts teams might have at the clause level: task conflicts about the matter at hand; process conflicts about scheduling, plans, priorities, and the like; and relationship conflicts, in which participants dislike one another or react negatively to another's manner. Some conflicts have more negative emotion associated with them than others. The researchers found that the relationship between conflict and analogies is complex. The introduction of analogies from within a domain (both elements of the analogy are within the same domain) tended to spark both task and process conflicts, which may be constructive. On the other hand, process and negative conflicts, but not task-relevant conflicts, significantly preceded within-discipline analogies, but not within-domain (very close) or very distant analogies (Paletz, Schunn, and Kim, 2013).

Paletz noted that the environment can influence the sorts of conflicts that develop and whether they are mostly constructive or not. According to Paletz, "some places really encourage dissent and encourage disagreement and create what's called psychological trust so that you can disagree without feeling like it's going to get personal. And that's of course where disagreement is going to be the most useful."[32]

OPTIMIZING EXAMPLE DISTANCE TO IMPROVE ENGINEERING IDEATION

Chris Schunn, University of Pittsburgh

Chris Schunn presented his research on the creativity process in engineering design processes. His main premise is that analogies to nature or other human designs are frequently cited as major sources of innovative ideas in engineering. Schunn argued that little is known about how to efficiently find the right analogies. One complicating factor

[32]For more details on this research, see Chan, Paletz, and Schunn (2012); Christensen and Schunn (2007); Paletz and Schunn (2010); and Paletz, Schunn, and Kim (2013).

is that the space of possible analogies is quite large. For example, just restricting to the U.S. Patent database, there are ~10^7 patents to consider.

One approach to organizing a search through possible analogies is to put possible sources into a structure. But on what should basis the structure be developed—logic, lexical, or conceptual? Schunn and his colleague used a new Bayesian approach developed by Griffiths, Kemp, and Tennenbaum (2008) to empirically discover the structure in data. Their process allowed them to "bottom-up discover" that color is best represented as a wheel, animals as a tree structure, and the U.S. Supreme Court as a line. Schunn's research team augmented this approach using Latent Semantic Analysis developed by Landauer, Foltz, and Laham(1998) to capture the basic semantics of text in patent descriptions. They then used Kemp and Tennenbaum's algorithm to determine which kind of structure best organizes the data. It turns out a tree structure provides a good fit to the text similarity data.

Schunn then explained how they tested the approach on an actual engineering design problem: design a device to collect energy from human motion. They took a random set of "mechanical" patents from the U.S. Patent database and organized them using their algorithm. As part of the experiment, they used 72 undergraduate mechanical engineers, who were randomly assigned to one of three different conditions:

Near: see 5 patents considered close to the design problem in the semantic tree
Far: see 5 patents considered far from the design problem in the semantic tree
Control: given no patents prior to being asked to solve the problem

Design solutions that were generated by the experimental subjects were coded for both novelty and quality.

Describing the findings of his project, Schunn said that the "Far" condition did worse than the "Control" or the "Near" conditions on both aspects of assessment—novelty and quality. This finding was the reverse of a previous study by his team, for which they used hand-selected patents instead of randomly chosen patents for their experiment (see Chan et al., 2011). To understand the difference in outcomes, Schunn and his colleagues added the previously used hand-selected patents to their 45 randomly selected patents, and re-ran the algorithm. They discovered that their near and far hand-selected patents were all closer to the design problem than the randomly selected patents that had been organized into relatively near and far. Thus, they essentially identified an inverted U-shape in the design quality and novelty data: very near patents are of no help, medium-distance patents can be useful, but very far patents are also of no help.

In conclusion, Schunn remarked that the result of his work expands notions of distance beyond the simple near/far binary distinction that is commonly used. His study also provides an objective distance function that can be used in research and practice to guide optimal analogy searches.[33]

[33]For more details on this research, see: Fu, Chan, Schunn et al. (2013); Fu, Chan, Cagan et al. (2013); and Chan et al. (2011).

LAB-BASED SOCIO-TECHNICAL COLLABORATIONS
Erik Fisher, Arizona State University

Erik Fisher observed that scientists and engineers are increasingly coming under pressure not just to produce societal benefits and contribute to economic growth, but also to consider societal and ethical factors as they make decisions in their work. “This is a relatively new type of discourse in science policy,” he remarked, and it is known as the socio-technical integration mandate. This mandate differs from others that have affected scientists, in that it puts the burden on scientists and engineers to participate in the integration work themselves, rather than simply taking note of ethical, legal, or societal implications of their work. An example of this sort of formal policy, Fisher explained, is the U.S. Nanotechnology Act of 2003, which calls on scientists to integrate research on the societal, ethical, and environmental implications of research and development in the field of nanotechnology. This requirement was unprecedented at the time the law was written, in Fisher’s view, but similar policies have been pursued in other countries.

This approach is a switch from thinking about the effects of policies on scientific choices to thinking about the effects of scientific choices on policy outcomes. Legislators “… are essentially saying that scientific and technological trajectories are in part the aggregate result of numerous individual decisions and choices that scientists make,” Fisher explained. The authors of the nanotechnology legislation and other similar laws and policies acknowledge, however, that, as Fisher noted, “well, maybe this isn’t even possible,” because it is a new way of thinking about science.

In response, researchers have begun to explore what is possible in this regard. Fisher described a project called Socio-Technical Integration Research (STIR), which is a coordinated set of studies of laboratories in which researchers examine the capacity of scientists to integrate broader societal concerns into their work in response to the pressures on them to do so. This work involved 27 laboratories within 14 countries, located in North America, Western Europe, and East Asia. Social scientists were “embedded” in these laboratories for 12-week periods to engage in interdisciplinary collaborations with scientists and engineers in order to identify and reflect on societal issues, and also to document the results.

The project was grounded in a theoretical model of decision making in a laboratory setting termed “midstream modulation,” Fisher explained. The model reflects the fact that laboratory scientists factor many dimensions, including ethical ones, into their thinking, but that they are not trained to do this in an explicit way. Thus, in the STIR project, the embedded social scientists observed the decision making and challenged the laboratory practitioners to think more explicitly about the social context in which work fits. The social scientists used a protocol for midstream modulation that essentially asks the laboratory scientists questions such as: “What opportunities are you responding to? What are the considerations that are going into your response? What are the different alternatives you have to move forward? And where do you think this is going and why might it matter, who will care about the decisions that you make?”

Often, Fisher explained, at the beginning of these experiences, the scientists do not recognize that their work involves decision making, but as the questioning highlights the decisions they do make, they begin to see their work “through the social scientific lens.” He suggested that, in many cases, the scientists began to make decisions more deliberately as a result of this experience and recognized environmental and safety concerns they had not previously seen. They made changes in experimental procedures and waste disposal, for example, and even found new ways to adapt research procedures in ways they had not thought were viable. Several of the changes lasted or took place after the social scientists left the laboratories, Fisher noted, such as altering the direction of a research project, instituting collaborative decision-making processes, or developing public outreach programs. In other cases, tradeoffs were examined more deliberatively but tensions remained unresolved.

More important than changes in material practice, for Fisher, were the changes in the laboratory scientists' thinking. Prior to one study, most industrial researchers who participated indicated that the integration of societal concerns was not one of their core professional obligations, whereas by the end of the study, all agreed that it was. Fisher noted that many scientists and policy makers believe that this sort of integration is not possible, or that if it were possible, it would be undesirable. Not only would it undermine the scientific process, some believe, it would "slow down research and development." In his view, the STIR project has demonstrated both that socio-technical integration is possible and that it has utility: "It aids scientific creativity and expands decision making." Making science more responsive to societal concerns and demands also enhances its public value, he added.

Fisher closed with the observation that the laboratory is not just an instrument of policy, but also a policy actor, and that "the decisions made in the laboratory have implications for policy outcomes." Science is largely self-governed, he noted, which has been a barrier to previous attempts to institute socio-technical integration, "because science is set up to protect itself from societal concerns." But the mechanisms of self-governance are also "powerful forces for deciding what and how and when to consider and respond to societal questions that are normally taboo." Scientific research can contain the potential for "explosive conflicts," he added. The function of socio-technical integration is to "bring these conflicts to the fore more often, more regularly, at multiple levels, not just after commercialization in public debates and in regulatory decisions, but at the site of knowledge creation."[34]

THE VALUE OF SCIENCE
Gary Bradshaw, Mississippi State University

Gary Bradshaw observed that something remarkable happened between approximately 1000 AD and 1900 AD that is visible in graphs of many different phenomena. He showed the similarity of graphs of world coal output, energy use, sugar consumption, speed of transportation, life expectancy, gross world product, and world population over the past 200,000 years: each was essentially flat for most of the period and then abruptly veered upward, virtually at a right angle. "You cannot fit even an exponential function" to this sort of graph, he pointed out, "so what happened?" Clearly, there were dramatic developments in manufacturing, agriculture, medicine, transportation, and other areas, more or less at the same time.

[34] For more details on this research, see Fisher and Schuurbiers (2013); Flipse, van der Sanden, and Osseweijer (2012); and Rodríguez, Fisher, and Schuurbiers (2013).

Focusing on the period between 1000 AD and 1900 AD, Bradshaw pointed to several key developments (see Figure 4-1). Population began its sharp increase, and the increase for gross world product was even sharper. Three events that fueled the industrial revolution occurred within this period: the founding of the Royal Society of London for Improving Natural Knowledge in 1660, the publication of Galileo's first book (1638),[35] and the invention of the steam engine in 1775. Galileo's work was important because "the science that predates Galileo wasn't experimental in the sense that we understand today," Bradshaw explained. Galileo recognized the importance of precise measurements; invented instruments with which to record data, such as the water clock, ruler, thermometer, and telescope; and introduced the idea of a scientific report that included a description of the methods used in the investigation.

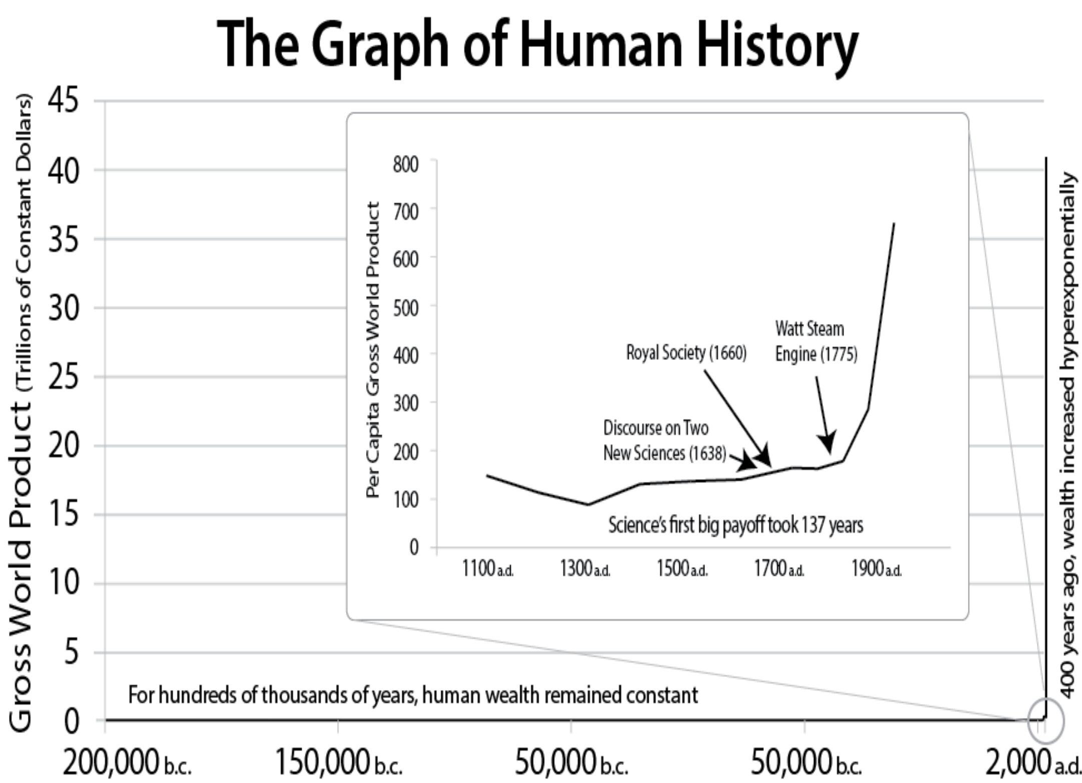

FIGURE 4-1 The Graph of Human History.
SOURCE: Presentation to SciSIP Policy Investigators' Conference by Gary Bradshaw, 2012.

[35]*Discourses and Mathematical Demonstrations Relating to Two New Sciences*, available at http://oll.libertyfund.org/?option=com_staticxt&staticfile=show.php%3Ftitle=753 [January 2014].

The sharp turns in the graphs demonstrate the value of this contribution, Bradshaw explained, noting that “99.66 percent of the gross world product is attributable to science.” The development of the steam engine, which grew out of 10 years of experimentation, was “the first big payoff.” Many scientific findings, however, lie “inert” for a long time before they are applied. For example, incandescence was demonstrated in 1802, but it was not until 75 years later that Thomas Edison developed a practical light bulb, while the Wright brothers applied research that was 100 years old in inventing a workable airplane. In both of these cases, experimental research was needed to build on the basic science that supported the invention.

These examples illustrate an idea that remains relevant today, Bradshaw suggested. Experimental research provides the foundation for technological developments (such as the current transition from incandescent light bulbs to more energy-efficient ones), but basic science has value undiminished by time. “Nearly every moment of our lives we exploit 200-, 300-, even 400-year old science,” he noted, and the opportunity for many technological improvements lies in currently “inert” science. Many scientists are not particularly skilled at recognizing the commercial applications of their findings because their job is to make the discoveries. Some companies are good at tracking scientific developments, but much that has commercial potential is missed.

Improving the science-to-technology pipeline is an important policy goal, in Bradshaw’s view. One possible way to accomplish that would be to provide governmental support for efforts to transition science to practical applications. “In many areas, there is little or no corporate support for transitioning inert science into valuable technologies,” he said. Bradshaw closed with his own view of science funding, which is that governments invest modest amounts of money in scientific research, “often with the belief that these investments will have immediate economic benefits.” The scientific evidence for this belief is “patchy,” he added, though “hundreds of thousands of years of human experience demonstrate conclusively that science has both near-term and long-term benefits.” These benefits have had a profound impact on individual and societal wealth. “The fastest way to exploit science for economic benefit is to leverage inert science,” he asserted.

HIGHLY CREATIVE RESEARCHERS
Jan Youtie, Georgia Institute of Technology

Jan Youtie observed that research on highly creative scientists tends to focus on individual abilities, article citations, or the prestige rankings of universities, while less attention has been paid to the effects of career and organizational factors on scientists’ creative performance. These are important though, in her view, because policy interventions can more easily address the structures that affect scientists’ career paths than other factors. She and her colleagues explored policy and management interventions that affect scientists’ careers in two fields—human genetics and nanotechnology—in the United States and in European countries.

Youtie and her colleagues began with a consideration of how to define scientific creativity and identified five ways in which it might be expressed, shown in Table 4-1.

TABLE 4-1 Types of Scientific Creativity

Type of Scientific Creativity	Examples
Formulation of new ideas that open a new cognitive frame or bring theoretical claims to a new level of sophistication	Theories of specific relativity (physics) Einstein (1905)
Discovery of new empirical phenomena that stimulate development of new theories	Biodiversity and the theory of evolution (biology) Darwin (1859)
Development of new methodology for empirically testing theoretical problems	Factor analysis and theory on mental abilities (psychology) Spearman (1904, 1927)
Invention of novel instruments that open up new search perspectives and research domains	Scanning tunnel microscopy and nanotechnology (physics) Binnig and Rohrer (1982)
New synthesis of previously dispersed ideas into general theoretical laws that permit analysis of diverse phenomena in a common cognitive frame	General systems theory (biology, cybernetics, sociology) Bertalanffy (1949); Ashby (1956); Luhmann (1984)

SOURCE: Presentation to SciSIP Principal Investigators' Conference by Jan Youtie, 2012; adapted by Youtie based on Heinze et al. (2007).

They used this definition in a survey of active scientists, including some who are widely cited and are also journal editors in the two fields, and asked them to nominate highly creative researchers. Using these nominations and prize awards, they identified 76 scientists who met the criteria for high creativity. They then looked for scientists who had very similar characteristics (e.g., subject area, year of first publication, number of publications, subject area, productivity in first 6 years) early in their careers but who had not achieved the same degrees of recognition to serve as a control group. They requested CVs from scientists in both groups in order to identify matches for comparison.

Youtie and her colleagues developed models of early and mid-career pathways they hoped would accurately predict the differing outcomes for the target and control groups. Variables for the early career stage included time to earning a degree, having a postdoctoral appointment, international experience, and the like. For the mid-career stage, the variables included time to achieving tenure, number of total and nonacademic positions held, number and diversity of grants received, and collaborations.

The comparisons of the U.S. and European experiences highlighted both differences and similarities at both stages, Youtie reported. For example, moving quickly through schooling and up the promotion ladder is beneficial everywhere, but more so in the United States; in Europe having international educational experiences has more weight than it has in the United States. Interdisciplinary training is more highly valued in the United States than in Europe, as are professional prizes and opportunities to work in nonacademic jobs. These results, Youtie concluded, suggest that more streamlined doctoral requirements would particularly benefit U.S. researchers, while expanded international opportunities would particularly benefit European ones. Both groups, she added, would benefit from more access to mentors who could offer guidance about career choices.[36]

PRIVACY AT AN INTERDISCIPLINARY RESEARCH INSTITUTE

Noah Weeth Feinstein, University of Wisconsin, Madison

According to Noah Weeth Feinstein, many scholars of science and science policy have concluded that contemporary science is different in significant ways from what came before it. One key difference lies in perspectives on treating research as public or private. Citing an influential book on the subject, *The New Production of Knowledge* (Gibbons et al., 1994), Feinstein noted that some “make the claim that contemporary science … is both somehow more public—in the sense that it has greater social relevance, takes place in the context of application, and has greater or different forms of accountability—and also somehow more private, in [its] organizational heterogeneity, the mix of public and private institutions [involved], and the emphasis on time to market.”

Feinstein and his colleagues investigated this tension in the context of a single institution, the Wisconsin Institutes for Discovery,[37] which resulted from the combined efforts of the University of Wisconsin, Madison, the Wisconsin Alumni Research Foundation, and a private donor to create an organization that would be responsive to the evolving nature of science. The founding of the institutes was inspired in part by the political controversy over stem cell research—the University of Wisconsin had been a leader in this type of research, and was concerned about maintaining its leadership in foundational research if there were new restrictions on research using stem cells. The design of the building was also a critical aspect of the plan for the institution. The building houses two research organizations: a private, nonprofit institute focused on biomedical research and a public university-affiliated institute. It also contains a large, open, and publicly accessible space called the “Town Center,” which occupies the ground floor.

Feinstein and his colleagues used oral history interviews, archival materials, and media coverage of the Wisconsin Institutes for Discovery to compare the institutes’ goals with the actual experiences of those who have worked there and those involved in the institutes’ early development. They began with the Town Center, which houses a café and restaurant and other spaces for collaboration. It was planned to allow university undergraduates and the general public to interact with the investigators in the building. The actual research is carried out on upper floors not accessible to the public or to most University of Wisconsin staff, faculty, and students. The space on the upper floors is also

[36]For more details on this research, see Heinze et al. (2007); Youtie, Shapira, and Rogers (2009); and Youtie et al. (2013).

[37]For more information, see http://discovery.wisc.edu/discovery [January 2014].

divided between the public and private research entities, and there are legal restrictions on the types of research that can be carried out in particular zones. Even on the private side, where certain restrictions on stem cell research do not apply, there are limits on the sorts of collaborations with private industry that are permitted, Feinstein added.

Using these and other examples, Feinstein and colleagues argue that organizational divisions have been established between the general public and all of the scientists, between non-institute scientists and institute scientists, and between the scientists associated with each of the institutes housed in the building. Depending on one's perspective, the same scientist can be both a member of the private, inaccessible community of science and a member of the public, excluded from the work of a particular institute. In short, there was not a single clear barrier between private and public science, but rather multiple lines that may be drawn in different ways. Although the creation of the institutes was intended to bridge barriers between public and private, it has had the perverse effect of creating a new set of barriers as well.[38]

ETHNIC COMPOSITION OF RESEARCH TEAMS
Richard Freeman and Wei Huang, Harvard University

The pool of scientific researchers has grown increasingly diverse. As Richard Freeman explained, large numbers of foreign-born scientists have immigrated to the United States as students, post-doctoral researchers, and fully qualified scientists. Published papers are increasingly likely to have multiple co-authors, and, in particular, collaboration among international colleagues has increased. Freeman and Wei Huang explored the ethnic composition of collaborative scientific teams and its relation to team productivity. They calculated the extent to which U.S.-based researchers tend to work with colleagues of the same ethnic background and whether that tendency influences the impact factor of the journal and citations to papers.

Freeman and Huang examined papers published between 1985 and 2008with two, three, or four authors in the Web of Science dataset that covers all of the science and mathematics disciplines. Using a tool for linking last names to ethnicities, they calculated the difference between the actual proportion of author teams with shared ethnicity and the proportion that would be found if the co-authorship were based on a random drawing.

Freeman noted that collaboration that leads to co-authorship of published articles could be thought of as a search process in which researchers seek out potential collaborators who are most likely to improve their work. He compared the process to the dating market, noting that the potential collaborators a researcher might meet will vary by geographic location, field of study, degree of seniority, and other factors. People might have a tendency to work with people who are like them because they are more likely to meet such people than other people, or because they share interests or find it easier to communicate. According to Freeman, if researchers choose collaborators based on shared preferences, the result may be lower productivity, whereas if they do so based on ease of communication, the result may be higher productivity.

Freeman and Huang developed an index of homophily, the formal name for the "bird of a feather flock together" tendency to associate with others of the same

[38]For more details on this research, see Kleinman, Feinstein, and Downey (2012).

background in various activities. They found a substantial degree of homophily in the authorship of scientific papers. Far more researchers work with people of the same ethnicity within detailed scientific fields than would be expected if researchers of different ethnicities met by chance and randomly chose to work together. Table 4-2 shows their calculations for papers with three authors. The first column gives the actual percentage of papers on which authors of the given ethnicities all had the same ethnicity. The second column gives the expected percentage of papers in which all three authors had the same ethnicity if authorship were randomly chosen from the ethnic distribution of all authors. The ratios above one in the third column show statistically significant homophily.

Freeman and Huang also explored the relation between homophily and the impact factor of the journal in which scientists published a paper and the frequency with which their papers were cited. The impact factor was lower when all authors were of the same ethnicity. Citations were also lower, though the relation was mediated in part by the impact factor of the journal. Looking at other characteristics of papers and authors that affected impact factors and citations, Freeman and Huang found that research teams with different addresses and that referred to more articles produced papers that were published in better journals and had higher impact factors.

TABLE 4-2 Comparison of Actual Percentage of Authors of Same Ethnicity with Expected Percentage, Based on Random Selection of Authors, in Three-Authored Papers

Ethnic Group	Percentage of All 3-Authored Papers with All Authors of Same Ethnicity	Expected Percentage Based on Random Draw of Authors from Ethnic Distribution of All Authors	Ratio of Actual to Expected Percentages (> 1 → homophily)
English	13.34	11.30	1.18
Chinese	1.24	0.09	13.32
European	0.22	0.16	1.35
Hindi	0.31	0.02	15.44
Hispanic	0.07	0.01	14.27
Japanese	0.09	0.00	205.53
Korean	0.20	0.00	117.68
Russian	0.30	0.00	16.64
Eight groups	18.20	11.58	1.57

NOTES: Based on 569,305 papers with three authors in WOS, 1985-2008. Ethnic group Vietnamese not reported due to small numbers. Ratios calculated by taking statistics to 5^{th} decimal places (not given in this table).
SOURCE: Presentation to the SciSIP Principal Investigators' Conference by Richard Freeman, 2012.

The implication is that the more diverse the research team—by addresses as well as ethnic mix—and the more diverse or wider the knowledge base as indicated by references, the more successful the paper was. Finally, they also found that the publication record of the first and last authors in a paper also contributed to its impact factor and the number of citations it received.

SCIENTISTS' CAREER CHOICES AND TRAJECTORIES

Rajshree Agarwal, University of Maryland

Rajshree Agarwal described two studies she and her colleagues have done on career choices that face young scientists. Both studies were intended to shed light on a tension that has developed between the worlds of academic and industrial research. Some in the academic world have suggested that industrial researchers cannot be expected to produce "breakthrough ideas," she explained, while from the industrial side, some perceive that "academia has failed us." In this context, young scientists are deciding between careers focused on basic research—the pursuit of knowledge for its own sake—and applied research—intended to meet a recognized need. She and her colleagues used survey and other data available from the NSF Scientists and Engineers Statistical Data System (SESTAT)[39] to explore the choices these young people make, the factors that influence them, and their earnings trajectories.

Career paths are not strictly orthogonal with respect to academic versus industry location of work, Agarwal noted. More than 21 percent of scientists who have academic positions focus on applied science; on the other hand, 13 percent of those with jobs in industry focus on basic science. She and her colleagues found that young researchers with "a preference for non-monetary returns" tend to choose academic jobs over industry jobs, but not necessarily to choose basic science over applied science. Ability is another factor in this sorting, with higher ability researchers choosing basic over applied research if they are in academic jobs, but not necessarily doing so if they are in industry jobs. Moreover, researchers doing these two types of work are much more likely to collaborate with one another if they are in industry jobs than if they are in academic ones. She suggested that policies to better support young researchers making career choices, and to break down academic silos, would be beneficial.

In general, Agarwal explained, earnings do not closely track the simple choice between basic and applied research. Earnings are typically lower in academia than in industry, in part because there is a higher preference for non-monetary returns among academic researchers. Also, earnings between basic and applied researchers in academia diverge, but are very similar in industry, in part because the greater collaboration across research types in industry causes both types of researchers to benefit from higher productivity.

In a second study, Agarwal and her colleagues examined the gender gap in earnings, with women who work full time currently earning just over 80 percent of what

[39]SESTAT is a project of the National Center for Science and Engineering Statistics; for more information, see http://www.nsf.gov/statistics/sestat/ [January 2014].

their male counterparts earn.[40] Agarwal noted that in analyses that controlled for factors such as ability, demographics, and family status, the gender gap is higher in academia than in industry. While the gender gap is lowest at the start of careers in both work places, the divergence in academia over time is greater than in industry. She noted several possible explanations, including that women in academia may have fewer career options when they are striving to coordinate with a partner's career, that childrearing responsibilities may disproportionately affect academic women's careers particularly when experienced in the pre-tenure years, that "good old boy" networks may be more persistent in academia, and that women in academia may be more likely to be segregated into lower paying sectors than those in industry.[41]

SKILLED IMMIGRANTS AND INNOVATION
Eric Stuen, University of Idaho

The United States has been a global leader in research and development, both within the university system and in high-tech industries, observed Eric Stuen, but many have wondered why that is so given the deficiencies in its education system. He noted the possible connection between the nation's leadership in these areas and the large increase in enrollment of foreign students in U.S. Ph.D. programs between 1980 and 1995. The presence of these students could have influenced research outcomes, and many may also have stayed on in this country as researchers and recruited colleagues. Overall, Stuen estimated, one-third of Ph.D. students in science and engineering are foreign born and two-thirds are U.S. born. He also commented that 62 percent of foreign-born students on temporary visas remain in the United States 5 years after completing their degrees.[42]

Stuen observed that some have criticized programs designed to attract and support foreign students who want to study in the United States on several grounds.[43] After the September 11, 2001, terrorist attacks, he noted, the U.S. Congress placed limitations and checks on student visas that were considered after that date. Current immigration bills under consideration would expand access to work visas and green cards, which indirectly encourages enrollment in Ph.D. programs. Thus, Stuen and his colleagues explored the impact of enrolling different sorts of students in Ph.D. programs and how visa and scholarship programs can best support research in the United States.

Stuen and his colleagues used a knowledge production function to link research inputs and outcomes and to identify enrollment fluctuations and attempt to link them to macro-level influences, such as China's lifting of restrictions on study abroad in the 1980s. They culled a variety of sources for data, including enrollments, publications and

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[40]Data are from the Bureau of Labor Statistics; see http://www.bls.gov/cps/cpswom2011.pdf [January 2014].

[41]For more details on this research, see Agarwal and Ohyama (2013); and Agarwal, Ding, and Ohyama (no date).

[42]This statistic comes from M.G. Finn (2012), the only scholar to study long-term stay rates with credible data. Stay rates of Ph.D. students vary widely depending on their country of origin, from only 5 percent from Saudi Arabia to 89 percent from China. See http://orise.orau.gov/files/sep/stay-rates-foreign-doctorate-recipients-2009.pdf [January 2014].

[43]See Finn (2012). One such program is the federal Fulbright foreign student program; see http://foreign.fulbrightonline.org [January 2014].

citations, and research and development expenditures. The researchers developed a model that was able to predict enrollment for U.S. and international students and found only statistically insignificant differences between foreign students and U.S. students in terms of the number of publications and citations that resulted from their enrollment. A second central finding was that foreign students whose enrollment was more sensitive to fluctuations in income, and hence more likely to be on scholarship, contribute more to research productivity than those who likely pay their own way.

Stuen concluded, first, that both international and domestic Ph.D. students contribute to science and that financial support for them has high returns. Second, he concluded that major reductions in programs designed to attract and support foreign science students would harm the scientific capacity of U.S. universities. Specifically, he added, the current visa policy that requires applicants who wish to study in the United States to demonstrate financial means hurts scientific productivity in the United States.[44]

FOREIGN-BORN STUDENTS WHO RETURN TO THEIR HOME COUNTRIES

Megan MacGarvie, Boston University

The United States educates a large share of the world's scientists, explained Megan MacGarvie, and in many fields foreign-born students are now the majority. She and her colleagues examined the results when these foreign-born students leave the United States once they have earned their degrees. She noted several possibilities. Students who return to their home countries may make research contributions to these countries and promote the diffusion of ideas around the world, but lose their links to the research community in the United States. If the research community in their home countries is not as productive as that in the United States, their contributions may be muted. There is likely a loss to the United States when these students leave: domestic scientists lose connections with scientists in other countries, and the nation loses the contributions of researchers who have traditionally been among the most productive.

Since its inception in 1946, the Fulbright Foreign Student Program has brought more than 128,146 students to U.S. graduate programs, MacGarvie explained. These students receive J-1 student visas that require them to spend 2 years in their home countries before applying for a permanent or work visa in the United States. Moreover, many countries have programs that require or encourage those who study abroad to return home after they earn their degrees. Students affected by these policies tend to spend about twice as much time abroad after earning their degrees as other foreign students do.

MacGarvie and her colleagues used citations of academic papers as an indicator of influence. They used those data, along with other data about a pool of 488 Fulbright scholars from around the world and from a variety of science and engineering fields, to determine whether those who were subject to the return requirement were cited more or less frequently by authors in their home countries and by authors in the United States than those not subject to such requirements. Analyzing the data using a variety of controls, they found that a key variable was the income status of the student's home country. Thus, low-income countries reaped a significant benefit from the return

[44]For more details on this research, see Stuen, Mobarak, and Maskus (2012); Maskus, Mobarak, and Stuen (2013); and Stuen (2013).

requirement, in terms of influence on their own research communities. On the other hand, the students from low-income countries affected by the return requirement ultimately had reduced productivity, compared with their peers. To be more effective, MacGarvie suggested, return requirements should be paired with policies designed to support research productivity in low-income countries. However, she suggested, there are likely additional unmeasured benefits in terms of improved access to scientific knowledge in lower-income home countries.

U.S. RESEARCHERS IN INTERNATIONAL COLLABORATIONS
Susan Cozzens, Georgia Institute of Technology

There is growing capacity in both science and engineering in many parts of the world, but "no country can really do it all by themselves anymore," Susan Cozzens observed. In her view, there are strong incentives for researchers around the world to learn from one another, and her research focused on the role that U.S. researchers are playing in international research collaborations, and the effects on them. The U.S. research workforce itself is quite international, she noted, and research teams include many people who were born outside the United States. U.S. researchers do less cross-border collaboration than those from other countries, though they report that they learn as much as their partners from such collaborations.

Cozzens and her colleagues investigated international collaboration in two fields—laboratory-based biofuels research and neutron-scattering research. They reviewed papers published between 2003 and 2009, conducted interviews with 60 researchers, and conducted an online survey of more than 2,500 researchers in the two fields (two-thirds were in the field of neutron scattering). Biofuels research became very popular in the early 2000s, Cozzens explained, and there are significant research centers in this area outside the United States. Neutron-scattering research is based on the use of large instruments, so it is primarily affluent countries that build the equipment needed to run the experiments.

There were no significant differences in the basic characteristics of the researchers from the two fields within the study pool, Cozzens noted. Among those in both fields, between 50 and 60 percent were born in the United States, and most were employed at universities, government laboratories, or other research institutions. In both fields the respondents were approximately 80 percent male and 20 percent female. These researchers work in fairly large teams, with a median team size of 12 for the biofuels researchers and 10 for neutron scattering; the teams generally have more than 40 percent international participation. In both fields, the amount of international experience researchers had before earning their degrees varied by country of origin and other factors, but by the time they become senior researchers, the vast majority had such experience. In both fields, however, U.S. researchers have among the lowest rates of international experience compared with those from other developed countries.

Cozzens noted that theoretical work suggests two primary reasons for researchers to collaborate. They might seek out the most powerful and influential collaborator they can find, which would likely result in asymmetric collaborations, or they might seek knowledge they cannot secure through their normal networks. The individuals she interviewed tended to match two categories well: the survey respondents engaged in situations in which either junior researchers were seeking new knowledge and skills or equal partners were seeking complementary knowledge and skills. The researchers, however, generally reported having learned as much from their collaborations as their team members did, regardless of their own status. Cozzens noted that the finding that research collaborations are often characterized by equal learning suggests that the theoretical model might need to be expanded.

INDIGENOUS BIOSCIENTISTS
Kimberly TallBear, University of California, Berkeley, and University of Texas, Austin

Kimberly TallBear conducted a study to answer the question of whether increased participation in science by Native American researchers will result in research that is more inclusive of and accountable to a broader sector of society and also more rigorous, or whether the result will simply be a more diverse population of researchers but no change in concepts or approaches. She used several kinds of sources and methods to explore this question, including a review of literature on the participation of Native Americans in science, demographic data from professional associations, interviews,[45] and participant observations at scientific meetings and training venues.

TallBear explained that her general approach is to explore both scientific communities and Native American communities as having cultural, bureaucratic, and knowledge-producing functions. She sees these similarities as a way to bridge gaps between them and to undercut a common view of science and society as separate and potentially conflicting entities. Because TallBear's own heritage is Native American, her research background has been shaped by concerns about the potential influence of scientific research on Native Americans and their tribes. She was also able to draw on her relationships with other Native American scientists and professional societies in conducting this work, which helped her identify those who actively identified with their heritage.

TallBear described a few conclusions from her work about characteristics that Native American bioscientists share. They "emphasize their situatedness," she explained, by which she meant that because they are often the first in their families, or even their communities, to go to a university, those communities may have little familiarity with scientific practice. At the same time, however, moral support from their families and communities is often key to their persistence. Many say, she added, that mentoring from older peers with "a Native way of looking at things" has also been a key support.

Native American scientists may also respond in unexpected ways to moral and cultural challenges, TallBear added. For example, Native American scientists may be uncomfortable with killing animals for research and prefer to use animals that have died of natural causes. Many also grow up with strong traditions that treat certain animals or objects as "profane." Owls, for example, are viewed as profane—a bad omen to be

[45]TallBear noted that, to date, she has interviewed members of the Dena or Navajo people, Ojibwa or Anishinabe, Seneca, Eastern Band of Cherokee, Colville, Laguna Pueblo, Yurok, Ohlone, and Onondaga tribes.

avoided—by the Navajo, so research involving owl pellets presents a challenge for scientists of that background. The Navajo also have strict rules about interacting with dead bodies, which has caused some science students to determine that they could not attend medical school. However, TallBear added, it has been possible for some to accept dissection of both humans and animals if the work is done "thoughtfully and with appropriate respect." Indigenous scientists have in some cases worked with other tribe members to create new ceremonies to address these ethical concerns.

In general, TallBear found, Native American scientists are able to travel effectively between reservation settings and university research laboratories. She used her interviews to ask about the congruence, and lack thereof, between traditional knowledge practice and university science. Many responded initially that the two are incompatible, but, when pressed, "acknowledge that there are elements of traditional knowledge that are very akin to the scientific method." What is most difficult for them to navigate are the social differences. In science there is "an ethic of individual inquiry and a right to knowledge," she noted, whereas those who develop traditional knowledge "have to be called and recognized by other medicine people," because of the spiritual element of the knowledge base.

TallBear concluded that Native American scientists have the incentive to develop scientific methods that are less destructive than they might otherwise be. Because scientific narratives have authority in policy making, she added, "it is prudent [for Native American scientists] to have a voice in the construction" of those narratives. At the same, Native American scientists "can contribute research questions, hypotheses, methods, and ethical approaches that are consonant with [their] cultural practices and knowledge priorities, rather than shaped solely by non-tribal research priorities and Western bioethical assumptions."

ORGANIZATIONAL SIZE AND DISCONTENTS

Jerald Hage, University of Maryland, College Park
Aleia Clark, U.S. Census Bureau
Jonathan Mote, George Washington University
Gretchen Jordan, 360 Innovation

Jerald Hage and his colleagues explored the influence of organizational size in six federally funded research laboratories. These laboratories are key components of the national innovation system and therefore for the economy, but the sites also provide unique opportunities to study sociological problems from a distinctive angle.

The original research design started with 75 research projects in six programmatic research areas: biology, chemistry, alternative energies, material sciences, and geosciences, as well as some interdisciplinary projects. The projects were selected with the aid of senior division managers in six national laboratories: three small (under 2,000 scientists), two medium (2,000 to 4,000 scientists), and one large (over 4,000 scientists). Hage and his colleagues encountered resistance from the laboratories' leadership and from the scientists themselves, but were ultimately able to collect at least two responses each on a specially designed research environment survey for 57 projects. Response rates varied by laboratory size, from 38 percent for the large ones to 64 percent for the small ones.

Hage summarized a variety of findings across a number of major areas of research: research activities, work satisfaction, learning, management qualities, and lab strategy. Across the six programmatic research areas, there were considerable differences in the amount of time allocated to basic research. For example, scientists involved in material sciences spent 44 percent of their time on research, while those in chemistry spent only one-quarter of their time. Time spent on seeking research funding was more than he had expected, ranging from 9 percent (alternative energy and material sciences) to 19 percent (chemistry). Despite these differences across programmatic areas, the larger the laboratory, the less time was spent on research and the more time was spent on seeking outside funding and on internal administration.

Not only did the scientists in the larger labs spend less time conducting research, but also organizational size actually affected the nature of the research process. Irrespective of programmatic area, scientists in the larger laboratories reported that their projects had less time for creativity, freedom to explore new ideas, and to take risks. Furthermore, these scientists wished that they had more time for these activities as measured by a discrepancy index measuring the difference between preferred and actual time allocations. In contrast, the programmatic research area had a strong impact on the different ways in which scientists learned. But despite this, scientist at the larger size labs also reported receiving less critical thought and greater discontent as measured by the discrepancy index. Consistent with this negative effect, managers were perceived to provide less technical value in the larger laboratories.

Not unexpectedly, the larger laboratories, even controlling for both intrinsic and extrinsic rewards, have less work satisfaction. Researchers engaged in interdisciplinary work were the most likely to score high on the satisfaction measures, while the scientists who have been in their jobs longest were the least satisfied. One might have expected that the larger laboratories would have more resources, but it appears that as reported by the scientists, they do not. This is another cause of less work satisfaction. One potential explanation for the larger laboratories having fewer resources and thus the necessity for external support is the scientists do not perceive that they are pursing innovative strategies likely to gain more resources. These findings, in Hage's view, demonstrate some important disadvantages to large laboratories: as he suggested, "it is time to rethink laboratory size." However, clearly more research is needed to further explore differences in laboratory structure and strategy by research area.

COMMUNITY ECOLOGY FOR INFORMATION TECHNOLOGY (IT) INNOVATION

Ping Wang, University of Maryland, College Park

Some innovations become very popular and reshape the landscape of information technology, noted Ping Wang, while others do not. Wang and his colleagues used a database of innovations they have been building, the Science and Technology Innovation Concept Knowledge-based (STICK: stick.ischool.umd.edu) to explore why some innovations are so influential. Social media, big data, and cloud computing are just a few of the innovations that are popular now, he noted. Most share a wavelike trajectory in popularity—moving rapidly from being unknown to a peak, and then declining almost as quickly—but some have much higher peaks than others.

Wang and his colleagues focused on cloud computing to investigate this pattern. The National Institute of Standards and Technology has defined cloud computing as "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (Mell and Grance, 2011). A diverse community is needed to support cloud commuting, Wang explained, including platform providers, application providers, adopters, public and private investors, researchers, analysts, consultants, and others, as well end users. "The general public is a stakeholder," he added, and media organizations are also heavily involved. Wang and his colleagues used ideas drawn from organizational ecology theory to explore the evolution of this community.

A process known as *legitimization*, Wang explained, describes the way in which an innovation and its community gain legitimacy. As the innovation gains legitimacy, more people and organizations join the community—and as more join, the legitimacy increases. After a certain amount of expansion, however, the community resources may be stretched thin and the crowding will cause competition. At this point, the rate at which new members join the community will drop off.

Communities of comparable size will vary in their popularity, Wang added, and thus other factors, such as community structure or the efficiency of community resource utilization, may explain that difference. He turned to a new theoretical model, scale-free network theory, to explore possibilities. A scale-free network, he explained, such as the flight route map of an airline, has hubs, or nodes, that are connected to many other points, while other points are not so well connected. This model is "highly efficient in diffusing innovation, information, rumors, or viruses," whereas a system with more randomly distributed nodes, none of which is better connected than others, is not. Thus, if two different innovation communities have comparable degrees of crowding but one is a scale-free network and the other is not, the negative effect of competition will be smaller for the scale-free one. Wang and his colleagues hypothesized that the more scale-free a community, the higher the rate of entry of new members into that community.

To test that hypothesis, they collected news articles about cloud computing published over a 5-year period and used automated tools to identify the organizations that were members of the cloud computing community. They used NodeXL, a free Excel add-on program, to construct a model of the interconnections within the community and identify clusters of connections that represent competitive and collaborative relationships among companies, investors, researchers, and so forth. Over time, the number of organizations involved and the clusters grew, and the network structure also became more complex.

Wang and his colleagues used the rate of new entries in a community as the dependent variable, the density dependence model (the dependence of community dynamics on community density) to represent the legitimization and competition in the cloud computing community, and the degree to which the community is scale-free to represent its efficiency of resource utilization. They looked at the entry rate over a 5-year period and found that it correlated positively with legitimacy and degree to which the community was scale-free, but negatively with competition. Overall, Wang noted, this model of community function explains more than 70 percent of the variance in entry rate over time.

Wang concluded from this work that ecology theory, conventionally applied to explain dynamics of individual industries, is applicable even to an innovation community that involves multiple industries. He believes that the approach they used, drawing on what is discussed and mentioned about innovations in published articles, or discourse analysis, is a useful way to capture the flow of ideas and resources across industries. Combining this analysis with crowdsourcing, natural language processing, and information visualization, he added, helped them to take the innovation discourse analysis to a larger scale.[46]

[46]For more detail on this research, see Sun and Wang (2012); and Shneiderman et al. (2012).

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Project Descriptions: 21st Century Data

Many of the SciSIP researchers have found new ways to collect and analyze data. Technological innovations have made it possible for them to examine questions that may have been difficult to study previously, for example, by mining large bodies of data for patterns and trends and using maps and other visual displays to illuminate relationships. Researchers have also expanded the kinds of data that can be collected to permit adequate evaluation of policy initiatives.

DATA MINING AND INFORMATION EXTRACTION
Lee Giles, Pennsylvania State University

Lee Giles observed that a significant portion of the data being generated today is in the form of text documents, but these data are unstructured and difficult to mine. This material may include business and government reports, blogs, web pages, news, scientific literature, online reviews, and more. If it is to be managed, searched, mined, stored, and used, it must be extracted and given structure. Information extraction has become an active area of research, Giles explained, and software development companies have begun to focus on it.

Giles and his colleagues have worked on an open source online tool, called SeerSuite, that digital libraries and search engines can use to index and extract information.[47] The tool uses algorithms to mine the Internet on a large scale and a variety of specific tools to improve the quality of information extraction. SeerSuite programs support research and are also used to train students in search and software systems. SeerSuite has been the basis for developing numerous additional Seers programs focused in particular areas. These include CiteSeer, ChemXSeer, ArchSeer, and CollabSeer, and others are under development or have been proposed. CiteSeer, which provides autonomous citation indexing, reference linking, full text indexing, and other features, has approximately 800,000 users, Giles noted, and covers approximately 3 million documents. CollabSeer recommends potential research collaborators based on characteristics of their previous work, and approximately 400,000 authors have participated. RefSeer recommends possible citations for a document related to a particular topic.

SeerSuite has tackled several key challenges in information extraction, Giles explained. A primary challenge is termed "disambiguation"—the difficulty of creating an automated system that can correctly deal both with multiple versions of the same name and with the prevalence of certain names. Part of the solution was the development of

[47] See http://sourceforge.net/projects/citeseerx/ for more information [January 2014].

EthnicSeer, which uses sequences of characters and phonetic sounds to classify name ethnicity. ChemXSeer was developed to perform a similar function with respect to chemical names, and programs have also been developed to deal with tables, figures, and other data structures. Another challenge has been taking the programs to scale, and Giles explained that they have been beta tested and brought to scale with the collaboration of many researchers. The result is an infrastructure for the creation of academic and scientific specialty search engines and digital libraries that is easy to use and to apply to new domains.

THE U.S. PATENT INVENTOR DATABASE
Lee Fleming, University of California, Berkeley

Lee Fleming used an example to illustrate the problem his research has been designed to solve, showing examples of three separate U.S. patents that had been issued in the same name. The patent information indicates that these are three separate individuals, but such data overlap makes searching for and identifying needed information much more difficult. He and a group of colleagues from diverse fields have used a set of algorithms to develop a search engine that can efficiently extract information from the U.S. patent database. They have used a range of resources, including public databases, Google, and the National Bureau of Economic Research, to collect primary datasets to test their disambiguation engine.

Fleming and his colleagues have tested the engine's capacity to learn in a variety of ways. Fleming closed with a few thoughts about the implications of this work for science and innovation policy. Non-compete rules tend to decrease the diffusion of people and ideas within regions, in his view. They drive the best people and ideas to regions that do not enforce them. Technology firms may favor them on the grounds that they provide a "hiring shield," he noted, but ultimately they may fall behind because it is difficult for them to hire new workers with fresh ideas. There is active controversy about these rules, Fleming added: China has just weakened these rules, the state of Massachusetts is considering weakening them, and the state of Georgia has just strengthened them. He suggested that a cohesive and productive research community can best be supported by policies that:

- Preserve precedence while providing both ongoing and intermediate results;
- Build community assets, including source code, data, and published results; and
- Support high standards in code development.

THE ROLE OF PRINCIPAL INVESTIGATOR AND INSTITUTIONAL CHARACTERISTICS IN SHAPING DATA-SHARING BEHAVIOR
Amy Pienta, University of Michigan

Amy Pienta and her colleagues used data on research awards in the social and behavioral sciences made by NSF and NIH to explore the influence of institutional policies on data sharing for the value of investments in science. The database was developed under the auspices of the Inter-university Consortium for Political and Social Research (ICPSR) and allowed Pienta and her colleagues to review thousands of records. They also conducted a national survey of 1,499 principal investigators in the social sciences, achieving a 27.4 percent response rate.

They categorized the grants awarded in the social sciences by NSF and NIH between 1985 and 2001 in terms of the degree of data sharing involved, flagging them as having used archived data, having informally shared data, or not having shared data. Combining this information with data about researchers' characteristics allowed Pienta and her colleagues to draw observations. For example, they found that there was variety across disciplines and institution types in willingness to share data. Economists and political scientists reported the most data sharing, while psychologists shared the least, Pienta noted. Tenured faculty members were more likely than others to archive their data, but non-tenured faculty did more informal sharing. Other individual characteristics showed fewer significant differences, she added, but investigators at private research organizations were the most successful at sharing data, especially informally.

The researchers who responded to the survey reported perceiving a variety of barriers to sharing their own data. The most frequently cited reasons were not having adequate time to prepare the data, finding it difficult to prepare documentation, and concern about protecting the confidentiality of research subjects. They also cited concern about the possibility that others would misinterpret the data or publish work based on it before they did. Some also thought others would not be interested in the topic. The two least frequently cited reasons were that language in their informed consent documentation prevented sharing, or that their institutional review board would not allow it.[48]

ENERGY POLICY FOR THE POOR
Catherine Eckel, Texas A&M University

Catherine Eckel and her colleagues explored the practical application of a policy tool by collecting data on the implementation of a federal policy, the Weatherization Assistance Program (WAP), in one Texas site.[49] WAP is designed to help low-income families improve the energy efficiency of their homes; it provides funds to states, which distribute them to a network of local governments, agencies, and organizations. The program supports activities such as an audit of a home's energy efficiency, installation of approved weatherization measures (e.g., caulking and insulation), and repair or replacement of inefficient heating or cooling systems.

Eckel and her colleagues used WAP data from Fair Park, a community in Dallas that is 70 percent African American and 26 percent Hispanic. The median annual household income is near the federal poverty line, and 50 percent of households that participated in the study have income below the poverty line.

Eckel and her colleagues collected baseline data on energy usage before the program was initiated in Fair Park. They also conducted a built environment survey, a survey of stores and food sources, and assessments of residents' physical activity and

[48]For more details on this research, see Pienta, Alter, and Lyle (2011).
[49]For more information about WAP, see http://www1.eere.energy.gov/wip/wap.html [January 2014].

other characteristics of the neighborhood. They built an experimentation station in the neighborhood that included a meeting room where the researchers could provide instructions and carry out associated activities. The data collection included a household survey covering demographics, time usage, crime and safety, housing, and expenditures. Household respondents were also asked about their participation in "green" activities, such as recycling, reducing car use, and composting. Participants were asked to play games designed to elicit their preferences with respect to such attitudes as risk tolerance, patience, and attitudes about conservation. The researchers obtained permission to collect energy usage data from local utilities. The data were also geocoded so that they could be linked to information about the physical attributes of buildings and neighborhoods in the study site, as well as data on WAP participation.

Only 16 of 233 homeowners in the study who were eligible for WAP took advantage of it, Eckel reported. They tended to be older than the sample and were more likely to have participated in local utility programs that suggest they were "paying attention." In Eckel's view, these results suggest the importance of considering indicators of a population's likeliness to take advantage of a policy such as WAP. Many people who are living in poverty, she suggested, are "just trying to get through tomorrow, and are not the people who are 'paying attention' to what is going on [with respect to] policy." Thus, in her view, it is important to include stakeholders from the beginning in designing policies so that they will reflect the needs of the communities they are intended to serve.

RETRACTIONS AND SCIENTIFIC COMMUNITIES

Jeff Furman, Boston University

Scientists make mistakes, and Jeff Furman noted the "perception that there is now more false science than there had been." His research examined scientific work that was retracted after having been reviewed by peers and published, and the role of institutions in the accumulation and regulation of accurate scientific knowledge. Economic growth requires new ideas that are easily accessible, he noted, and current research will be vital to future generations, just as contemporary scientists rely on what was learned in the past. Institutions, whether public or private, play an important role in establishing the policies that govern the generation of knowledge as well as how it is diffused and accumulated.

"Science must wrestle with the question of how much wrong information we are willing to tolerate," Furman explained. If the certification process—peer review and publication—were to eliminate everything about which there is some doubt, "we would likely be censoring material that is truly important," he added, but it is hard to measure the impact of published findings that are wrong. He noted that more than half of retractions take place within the first two years after publication, but he and his colleagues wondered whether retraction occurs in time. "We worry not about whether the [retracted] article is terrible, but about the amount of time spent building on it," he said.

Furman and his colleagues have conducted several studies of this process designed to support recommendations to industry and government. Their goal was to understand the drivers and implications of "false science." They used citation analysis of publications in the biomedical field to track what Furman called knowledge flaws. The

PubMed[50] database notes when a retraction occurs, so they were able to track retractions and explore the features associated with them. Unfortunately, he noted in response to a question, it is more difficult to track the reason for the retraction (whether error or fraud).

Furman and his colleagues found that retractions are becoming more common, that they usually happen swiftly, and that citations of articles that have been retracted decline by 50 to 80 percent. Papers that have the highest number of citations in the first year after publication have a higher probability of being retracted than those with fewer citations, and papers published by scholars at elite institutions have a higher probability of being retracted than those of other researchers. Publication of false information can have damaging effects, noted Furman. For example, a paper falsely demonstrating a connection between the MMR vaccine and autism led to a substantial decrease in vaccination rates in Europe, which in turn gave rise to outbreaks of measles. High incidences of retractions may also influence the reputation of a field, Furman concluded.

INTERDISCIPLINARITY

Alan Porter, Georgia Institute of Technology
Ismael Rafols, Georgia Institute of Technology

Interdisciplinary collaboration is regarded as important to innovation and beneficial in many other ways, but it is not easy to measure. Alan Porter, Ismael Rafols, and colleagues explored ways to measure and map integration and specialization and to assess the effects of interdisciplinary collaboration. In particular, they were interested in understanding the effects on the scientific output of interdisciplinary work and comparing national and international interdisciplinarity. Their approach was to track the transfer of knowledge across time, using measures of interdisciplinarity, and mapping the results. They began with metrics devised for the National Academies Keck Futures Initiative,[51] which was designed to spur interdisciplinary research in the United States. For the research publications covered by this program, they extracted cited references and used the Web of Science subject categories to classify them. With these data they created a matrix to show the interrelationships, and then calculated measures of integration (the breadth of subject categories referenced), specialization (the degree of concentration of publication activity), and diffusion (the diversity of citations).

Porter and his colleagues identified several approaches to mapping interdisciplinary work. Science overlay maps show the diversity of a body of work, while research network maps show how coherent it is. For example, Figure 5-1 shows a "meta overlay" map of citations in four areas of science. To complement the science overlay mapping, Porter, Rafols, and colleagues also used data on patents and data from the MEDLINE database[52] to produce visual representation of interdisciplinarity. For research network mapping, they used data on co-author collaborations, citations, and bibliographies.

[50]See http://www.ncbi.nlm.nih.gov/pubmed [January 2014].
[51]For more information, see http://www.keckfutures.org [January 2014].
[52]For more information, see http://www.nlm.nih.gov/bsd/pmresources.html [January 2014].

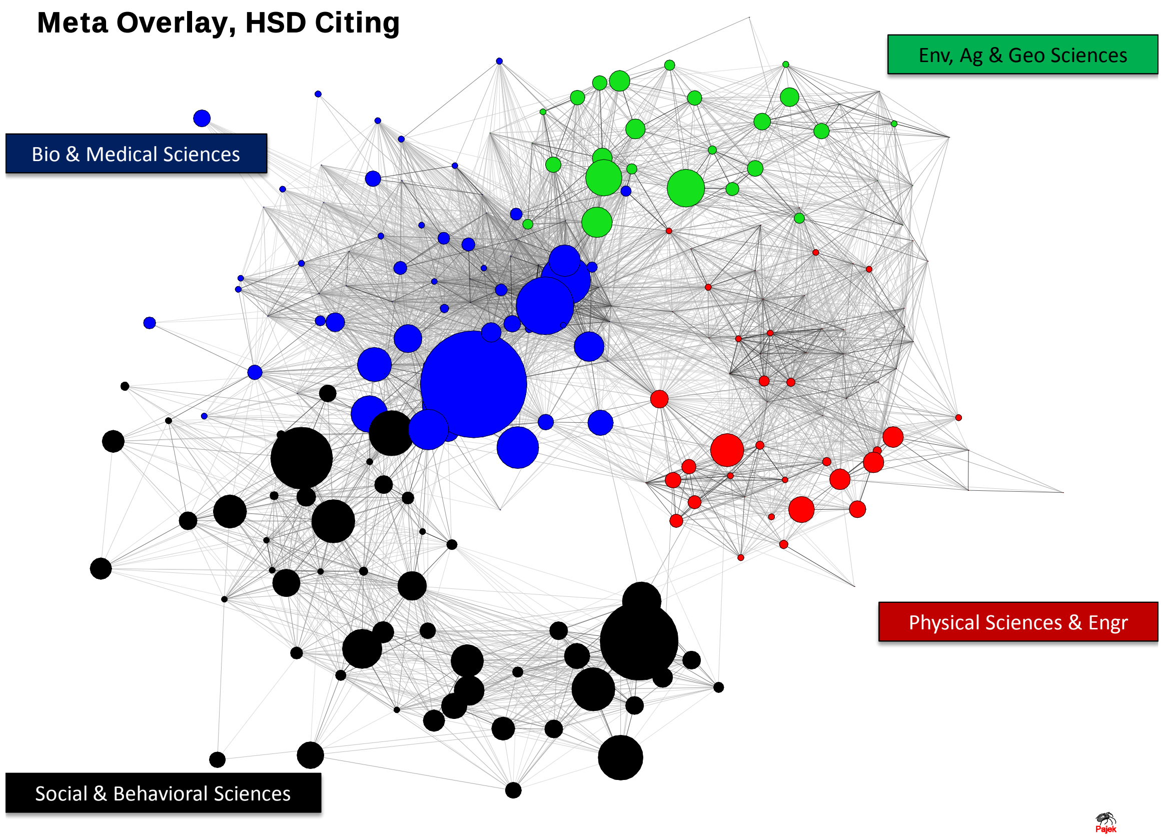

FIGURE 5-1 Meta-overlay map of citations in four areas of science.
NOTE: Green circles are environmental, agricultural, and geological sciences; blue circles are biological and medical sciences; red circles are physical sciences and engineering; black circles are social and behavioral sciences.
SOURCE: Presentation to SciSIP Principal Investigators' Conference by Alan Porter and Ismael Rafols, 2012.

SURVEY ON GLOBAL VALUE CHAINS
Tim Sturgeon, Massachusetts Institute of Technology

Tim Sturgeon used findings from a 2010 National Organizations Survey (NOS), supplemented with other data, to explore links between globalization and jobs in the United States. He and his colleagues obtained data on business functions (such as a firm's primary output, research and development, sales and marketing, transport and logistics, etc.), employment and wages, and sourcing practices (the costs of goods and services by business function and type of offshore location).

Their data covered 333 firms altogether, 198 of which had more than 500 employees, and 121 of which had fewer. For this sample, about two-thirds of employees are engaged in the firm's primary business function. More than half of the firms have at least one employee devoted to research and development. The survey finds that almost one-half (48%) of full-time employees work at organizations that have some domestic outsourcing, and almost one-quarter (23%) work at organizations that source internationally. International sourcing is concentrated in organizations in the goods producing and trade industry groupings. It is spread across all functions, including R&D, and is mainly carried out by large firms through foreign affiliates. Most international sourcing is to high cost locations, and secondarily to very low cost locations. Non-goods-producing organizations are more likely to source to low cost locations. Domestic outsourcing is concentrated in transport, IT services, and facilities maintenance business functions, and no consistent relationships between domestic outsourcing and employment or wages were found. However, international sourcing does appear to undermine low wage employment at home; it is related to relatively more high-wage employment and less low-wage employment by U.S. organizations.

In addition to these preliminary observations, the survey provides proof-of-concept, in the context of the United States, for the efficacy and usefulness of the data collection using a business function approach, an approach that has been used successfully by official data agencies in Europe and Canada.[53]

A QUALITY-ADJUSTED PRICE INDEX FOR CLINICAL TRIALS RESEARCH
Iain Cockburn, Boston University

Iain Cockburn and his colleagues analyzed trends in the costs of doing clinical trials. They focused on payments to clinicians by trial sponsors, and used "hedonic" price index methods to estimate the rate of inflation in commercial clinical trials from 1989 to 2009, controlling for trial characteristics. They looked at differences in the growth of cost rates across therapeutic areas, phases of clinical development, and degrees of demand in terms of time and resources. They also compared costs in the United States and other countries. It is difficult to understand trends in research productivity given the general inflation in the cost of doing research, which has been significant since the early 1980s, Cockburn noted. It could be that costs have gone up because researchers are tackling more difficult problems that require more resources, or it could be that costs have increased because of increases in the costs of salaries, facilities, instrumentation, and other resources. It would also be useful to compare trends in publicly and privately funded research, he added.

Cockburn and his colleagues used data on investigator grants from the MediData Solutions, Inc., database,[54] which included 225,000 records derived from contracts between sponsors and investigators. They coded the data for date, location, number of patients involved, therapeutic class, phase of development, and site work effort (a measure of complexity and difficulty of the research protocols). They found that the mean grant cost per patient grew fourfold from 1989 to 2009, while the site work effort grew threefold. In comparison to this sample, the costs of NIH-funded projects doubled. They used statistical procedures to analyze the data.

Cockburn offered a few findings about the increases they found. First, increases in "site work effort" had a large impact on overall cost increases. Inflation rates varied

[53]For more details on this research, see Brown, Sturgeon, and Cole (2013); Brown, Lane, and Sturgeon (2013); and Sturgeon et al. (2011).

[54]See http://www.mdsol.com [January 2014].

across different sorts of trials and sites, and the inflation rates were highest for the later stages of clinical work, when trials typically involve smaller numbers of patients per site. He noted that increases in overall expenditures reflect both the fact that more trials are being done and that substantial inflation has occurred in the average unit costs of this activity (which reflect both increases in quality and effort and increases in the prices of inputs such as wages, materials, and instruments). Cockburn ended by noting that it would be possible to use this type of data to construct a "constant quality" price index for private sector clinical research.

MAPPING ACADEMIC PATENTS TO PAPERS
Zhen Lei, Pennsylvania State University

Zhen Lei and his colleagues studied the influence of different sources of funding and licensure and patenting rules on the ultimate utilization and diffusion of inventions that are developed in a university setting. They focused on the chemical sciences and used two types of data. The first data set came from the University of California (UC) Office of Technology Transfer, which was able to provide data on invention disclosures and patents and licenses for the entire UC system. The second data set resulted from the researchers' work to scan publications in the chemical sciences by University of California researchers from 1975 to 2005.

The first step in the analysis, Lei explained, was to map patents granted to UC researchers to their publications. One might expect that each invention for which a patent application was filed would also have resulted in a published paper. In practice, however, a single patent application may be the result of multiple papers covering different aspects of the necessary research. Moreover, researchers whose first applications are rejected may publish numerous papers as they pursue ultimate approval. Lei and his colleagues used paper abstracts to identify content of inventions. They looked at the time relationship between publications and patents granted and traced the role of the lead researchers and their collaborators, as well as their university affiliations, in the utilization and diffusion of patented inventions.

Lei and his colleagues used statistical methods to review a set of patents, and developed an algorithm that identified links among publications, university policies, funding sources, and the ultimate influence of the inventions. The algorithm, Lei concluded, is a useful tool for studying the ways in which university inventions are put to use both within academia and industry, as well as the impacts of university patenting and licensing policies and government funding.[55]

[55]For more details on this research, see Oh et al. (2014); Oh et al. (2013); Drivas, Lei, and Wright (2013a, 2013b).

THE NSF PORTFOLIO EXPLORER
Leah Nichols, National Science Foundation

Leah Nichols explained Portfolio Explorer as a suite of automated tools, developed as part of the STAR METRICS Program,[56] that can track such features as topics, award data, the expertise of principal investigators, patents awarded, and geographic representation. NSF developed and piloted the Portfolio Explorer as a potential tool for planning and evaluation purposes. For planning, the Portfolio Explorer can help identify what research is needed to meet national goals, as well as what science is missing, emerging topics where new science needs support, and areas where interdisciplinary collaborations—between disciplines and across programs and directorates within NSF—can be valuable. The Explorer can also be used for evaluation of how well the portfolio has met past goals, and where its strengths and weaknesses lie. It can reveal the diversity of a portfolio and answer questions about how well a particular topic terrain is being covered.

This sort of portfolio analysis can be done in different ways, Nichols noted. If new projects are coded by topic, it is straightforward to analyze coverage for different areas, for example, but this sort of analysis cannot be done retroactively on projects that were not coded. In that case, the project abstracts can provide data on topic coverage, but reviewing the abstracts is labor intensive and limits the number of projects that can be covered.

A statistical text-mining algorithm was used to analyze and identify topics covered by the titles and project descriptions of all proposals submitted to the NSF between 2000 and 2011. In the Portfolio Explorer, all proposals were tagged with up to four topics each and also linked to other data, so that “you can use the topics to get at the awards and all the associated information, like award amounts, funding programs, PIs, PI institutions, and so forth,” Nichols observed.

Nichols has used the Explorer tools to assess cognitive and neuroscience research at NSF. She was asked to quantify how much of such research was being funded by NSF, what kinds of research, and which programs were funding that science. She and her colleagues identified 30 of the 1,000 topics in the topic model that were most relevant to cognitive and neuroscience research and used the topics to flag 3,000 of the approximately 100,000 awards funded in the past 5 years. The topics included, for example, stimulus and response, functional magnetic resonance imaging (fMRI), human vision, sleep, human motion, hormones, and many more. They cleaned the list for false positives—projects that were not actually relevant—and then tracked the selected projects to see which directorates contributed to their funding. They also mapped the topic-relationships of the projects and identified cross-directorate research themes.

In Nichols’ view, the topic model approach is valuable for several reasons, though she acknowledged that further validation work is needed. It allows for content-based characterization of funding portfolios that circumvents reliance on the institutional structure. It allows for rapid assessment of very large portfolios, and for retroactive assessment. (See the Measuring Interdisciplinarity project description below for more discussion of the topic model tool.)

[56] See https://www.starmetrics.nih.gov/ [January 2014].

MEASURING INTERDISCIPLINARITY
David Newman, Google

David Newman explained that interdisciplinarity, or collaboration across disciplines, has been measured in a variety of ways. For example, researchers have tracked citations and mapped them to identify the diversity and coherence of a particular portfolio of work. This kind of work has been helpful in demonstrating how interdisciplinary collaboration is rewarded, or not, in academia. It can also be used to trace the extent to which novel disciplinary collaborations can be found.

Another approach is topic modeling as discussed by Nichols above. Its advantage, in Newman's view, is that its algorithm uses data drawn from the research itself, rather than from institutional structures through which the research was produced, to produce categories and a picture of a body of work. "Topic modeling learns from bottom up," he noted. "It learns using the discourse of the investigators themselves."

The tool also can produce an interdisciplinarity score, Newman explained. The topic model identifies the top four topics for particular research and can assess how semantically different those topics are and how novel the interdisciplinary collaboration was, expressed numerically. These scores can be plotted to show the patterns for a particular body of work. This analysis revealed patterns in the work funded by NSF. For example, such programs as Antarctic Earth Sciences, the Continental Dynamics Program, and Sedimentary Geology and Paleontology ranked very high for interdisciplinarity, while Human Cognition and Perception, and General Age Related Disabilities Engineering ranked on the low end. The NSF has programs designed specifically to support interdisciplinary work, and the analysis showed that these programs did indeed produce work that scored high for interdisciplinarity.

The topic-modeling tool can be used to assess a body of proposals or grants awarded, by awarding entity, topic, publication etc., Newman noted. It complements citation analysis and helps investigators avoid pre-defined subject categories that may obscure interdisciplinary collaborations.

6

Perspectives on the Science of Science Policy

The conference provided opportunities for observers with a range of perspectives to offer their reflections on the work funded by SciSIP and the primary issues facing the community of researchers concerned with the science of science and innovation policy. Several presenters were asked to reflect formally on particular perspectives, and wrap-up sessions at the end of each day provided an opportunity for broad reflections from members of the steering committee. This chapter summarizes the points made by these speakers.

MODERN COMPUTING
M-H. Carolyn Nguyen, Microsoft Corporation

M-H. Carolyn Nguyen expects there will be “a radical transformation of our individual relationships with technology—computers—and what we expect from them.” She was asked to address upcoming trends in information technology research and the relationship between technology and policy, from the perspective of an executive at Microsoft Corporation. For her, one of the most important changes underway is a shift from computer systems that are driven by the technology itself to systems that are driven by the user. She suggested that several elements support a new understanding of what personal computing means, in which “an ecosystem [of technology] will work together on your behalf.”

A “seamless cloud connection,” she explained, will enable users to have access through their devices to the applications and services they need “at the right time, in the right context.” Thus, for example, a physician might have access to patient records whenever he or she is within the perimeter of the hospital, but not elsewhere. Part of what will make this seamlessness possible, she added, is technology that allows interactions to segue across different devices, so that users can continue an interaction as they move from their home computer to their car, to an office computer, or to a portable device.

The technology will adapt to the user’s needs, not the other way around, she emphasized, referring to this adaptability as “natural user interfaces or interactions.” The idea is that the technology adapts without the user having to learn how to operate or direct it. This capacity has already been applied in systems for people with disabilities—the systems are beginning to develop what she described as “human-like perception.” She noted that, “more and more systems can use and establish context to understand us and do things on our behalf, and then they can also, in order to refine that perception,… look at your interactions with peers to understand your behaviors.”

Another important trend Nguyen identified is that people's increasingly complex interactions with technology "are generating massive amounts of data:" in 2011, the amount of information created was more than 1.8 zetabytes, or 1.8 trillion gigabytes. Ninety-percent of that data is unstructured, she added, noting that data are a source of innovation and economic growth. "Data is the fuel that drives all these powerful technologies," she commented, but there is also "tremendous potential for abuse." In Nguyen's view, this is a key policy issue. She suggested that the best way to achieve balance between the benefits and potential harm will be to establish a "complete data ecosystem" in which individual users, policy makers, industry, and researchers from many disciplines, including the social sciences, work together to develop policies that balance the needs of all of these stakeholders.[57]

TRANSFORMATION IN SCIENCE
Elizabeth Wilder, National Institutes of Health (NIH)

Elizabeth Wilder described her thoughts about transformation in science, based on her experiences as director of the Office of Strategic Coordination at the NIH. That office is charged with identifying areas of science in which transformation is needed and using its funds to support researchers in those fields in overcoming challenges and pursuing opportunities likely to foster the needed changes. Wilder noted that transformation often takes place spontaneously in biomedical research: a remarkable, fortuitous discovery may open up entirely new fields. Her office, however, is focused on circumstances in which transformation can be pursued.

She and her colleagues have learned that most of the research at the NIH is initiated by creative investigators. In order to bring about transformation in a field, or engineered transformation, however, it is necessary to begin with a process in which a group of experts focuses on defining where the field needs to go and what needs to happen for it to reach those goals. For example, a series of NIH programs, funded over several years, were designed to make it easier to conduct interdisciplinary team research on biomedical topics. The programs focused on breaking down departmental barriers, and they were accompanied by administrative changes within NIH. Wilder believes that the result has been a "culture shift" and that many more people do now spontaneously consider interdisciplinary research.

Another program was designed to engineer an entirely new field of research on the extent to which the microbes that live inside and on the human body influence health. Developing this field of study was a daunting challenge, Wilder explained, because it involved the generation of new biocomputational informatics strategies. It was necessary to engage many researchers in sampling the biome in many healthy people and developing new computational and analytic methods. Demonstration projects were needed to shape understanding of what can be learned from differences across people in the composition of their biomes.

For this effort to work, Wilder concluded, it was necessary to have many researchers thinking collectively about the steps that would be needed to answer

[57] For more details on this research, see Bus and Nguyen (2013); and Nguyen (2013).

fundamental questions about the microbes, and also about how the investigators could work together to draw conclusions.

A FEDERAL PERSPECTIVE
Jason Boehm, National Institute of Standards and Technology (NIST)

Jason Boehm described the sorts of data that are needed at NIST and how they are used. NIST is “the nation’s measurement institute,” he explained, and its mission is to promote innovation and industrial competitiveness by advancing measurement science, standards, and technology. A federally funded, but non-regulatory agency, NIST runs collaborative institutes that address basic research in physics, biotechnology, quantum physics, and marine science. Their goal is to apply the research in ways that are useful to industry and help the nation solve problems and develop and deploy new technologies. The research expertise at NIST, for example, supports innovation in technology associated with lasers, memory, global positioning systems, and wireless communication.

This work puts NIST “right in the middle of big policy challenges,” Boehm explained. For example, NIST is helping to develop measurement tools and standards to promote cybersecurity, nanomanufacturing, and energy security. NIST has developed significant programs in these areas, but, as Boehm explained, there are still questions about the best ways to distribute funding, to develop public-private partnerships, and to assess results.

BIG DATA, SCIENCE METRICS, AND SCIENCE POLICY
Julia Lane, American Institutes for Research

Julia Lane noted that countries and agencies around the world are using evidence to inform policy decisions about public expenditures in such areas in health and education. This is not the case for science. However, the federal government has begun to require that agencies demonstrate their use of evidence in making investment decisions, and the Office of Science and Technology Policy has formed a working group to develop tools, data, and models that can be used to provide a more scientific, empirical basis for science and technology policymaking.

However, Lane noted, there is a significant gap in the data and tools policy makers need to do their jobs. An interagency group charged in 2006 with investigating the state of the science available to support policy decisions reached several conclusions:

- There is a well-developed body of social science knowledge that could be readily applied to the study of science and innovation.
- Although many federal agencies have their own communities of practice, the collection and analysis of data about the science and scientific communities they support is heterogeneous and unsystematic.
- Agencies are using very different models, data, and tools to understand their investments in science and technology.

- The data infrastructure is inadequate for decision making (National Science and Technology Council, 2010).

One of the problems, Lane suggested, is that the performance metrics used for science are not adequate. There is “an almost maniacal focus on counting publications,” she commented, which has “put the focus on publication rather than on thoughtfulness” (Lane, 2010). For example, she noted, it has been suggested that only about 10 to 15 percent of pharmaceutical assays published in peer-reviewed journals can be replicated (Young, Ioannidis, and Al-Ubaydli, 2008). An intellectually coherent theoretical framework will be needed, in Lane’s view, to provide the basis for accurate and valid measures. Research funded by SciSIP has played an important role in this discussion, she added, and it is one that needs to engage not only social scientists, but also scientists from physics, chemistry, and other domains.

The desired framework, according to Lane, should encompass measures that are timely, can be generalized and replicated, and are low in cost but of high quality. “That’s why the promise of ‘big data’[58] in the context of science policy is so interesting,” Lane commented. In her view, “the biggest single contribution NSF can make [through the SciSIP program] is to help build a data infrastructure that can be used by many science of science policy researchers.” The core of that effort, she added, would be the capacity to obtain disambiguated data on individuals and to develop new text-mining approaches.

This is a significant challenge, but computer scientists have been developing new ways to analyze and summarize text, Lane noted. For example, the NIH has collaborated with the National Science Foundation, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the White House Office of Science and Technology Policy to develop a program called STAR METRICS[59] to study the effects of research on innovation. That group has been working on automatically capturing information about scientists’ work through building on SciSIP-funded data collection activities.

According to Lane, one of the biggest challenges in this sort of work is building an infrastructure that is people-centered rather than document-centered (see Figure 6-1).

[58]In this context, “big data” refers to collections of data that are too large to be processed or managed by most data processing tools, such as data that can be collected in an automated way. New methods of processing and analyzing such data include the harnessing of large numbers of servers.

[59]For more information, see https://www.starmetrics.nih.gov [January 2014].

FIGURE 6-1 STAR METRICS conceptual framework.
SOURCE: Presentation to SciSIP Principal Investigators' Conference by Julia Lane, September 2012.

SCIENCE, TECHNOLOGY, AND INNOVATION POLICY IN JAPAN
Asako Okamura, Japan Science and Technology Agency

Science for Redesigning Science Technology and Innovation Policy (SciREX) is a Japanese program modeled in part on SciSIP, explained Asako Okamura, but it also reflects concerns specific to Japan. The 2011 earthquake and tsunami that affected Japan recently gave rise to a critical examination in that country of the relationship between scientists and the government. A growing expectation that science and technology will provide responses to economic and social challenges, she noted, has focused attention on the importance of evidence in policy. The development of evidence as a shared social resource that can serve as a foundation for public participation in policy formation was thus a primary goal for SciREX.

There are four elements to SciREX, according to Okamura: a policy-oriented investment investigation program, a research funding program funding similar to SciSIP, fundamental research and human resource development, and a data and information infrastructure. As it gets underway, SciREX has begun to engage universities in its network and also to reach out to international research partners.

Okamura went on to explain that the program faces a number of challenges. SciREX has not yet been able to map the various research fields the program hopes to address, and methodologies still need to be developed to "structure and synthesize outputs." Doing so will be critical for effectively integrating research findings into the policy process. At the same time, she added, the program needs to better promote the value of research findings, both to policy makers and to the general public. Okamura closed by noting that SciREX is already collaborating with U.S. institutions and is seeking other international opportunities to collaborate.

WRAP-UP THOUGHTS

Several speakers were asked to reflect on the issues and ideas raised at the conference. Irwin Feller, Pennsylvania State University and chair of the conference steering committee, cited the intellectual return NSF has gotten on its investment in these SciSIP-funded projects, and noted that "the real intellectual payoff is yet to come in larger research communities." He suggested that the dialogue that has begun among policy makers and researchers is a "great open invitation to the research community" to continue to tease out the policy implications of their work and how past work has influenced policy environments.

For Feller, an important unresolved issue is how to address uncertainty about research findings. Researchers are very aware of limitations to their findings. "What is the value to the policy world," he asked "of an answer that is cautious and conservative?" He noted that Jason Owen-Smith, in his presentation, had suggested that when one is challenged about the degree of confidence to have in a body of work, a solution may be to put it in probability terms. "Policy makers know there is no single definitive study," Feller noted, "as long as the researcher is transparent, they are glad to have the findings."

Benjamin Martin, Sussex University and member of the conference steering committee, provided a European perspective on what the U.S. science policy community is trying to do. He commended those involved for having built a science policy community in the United States. He noted that "there wasn't one before 2002—at least it was dispersed and fragmented." He noted, however, that science and innovation policy had a good start in the late 1950s, when the RAND Corporation in California gathered a "galaxy of future economics stars … to look at the future of economics and the management of R&D." There was a long interval between that and SciSIP, however. During the years following the RAND gathering, a whole host of dedicated science policy research centers were set up in multiple northern European countries. There were a few attempts in the United States during the intervening decades, and he said he wondered why those did not work.

Martin also had a few observations about the interaction between policy makers and researchers. He suggested there is not yet an optimal model for how this interaction can work. There is "pull" from policy makers who need information and "push" from researchers who have work they believe can be useful, as well as policy "entrepreneurs" who can mediate between the two, he noted, but added that "we are not there yet." A final question for him was the extent to which a researcher is "permitted to simplify and perhaps compromise and tailor what you have to say based on politics." Clearer rules about this may be needed, he suggested, noting that "we all have our own views. Some have gone glib and crossed a boundary—others never surface and get their message across." An effective model for the interaction will clarify this question, he concluded.

James Turner, Association of Public and Land-grant Universities and member of the conference steering committee, provided the final reflections on the conference, focusing on the policy relevance of the body of work SciSIP has funded. He noted that the work has both scientific and political merit and expressed appreciation for its contributions. "What SciSIP is really about is bridging cultures," he observed. As discussion about the STAR METRICS program suggested, engaging the field of anthropology in the study of science policy has been a particularly useful development.

Turner asserted that "you can't do your work right" unless the social sciences and the natural sciences learn how to talk to each other and cooperate on problems. This effort can be "quite a chore," however, because even within subgroups, researchers do not always understand one another. Like Martin, he believes that the more difficult challenge is making physical and biological sciences translatable to policy makers. One challenge is that there are different sorts of policy makers in the executive branch of the federal government, Congress, industry, state and local government, and think tanks.

Turner explained that his years working on Capitol Hill helped him to understand the "huge chasm" between scientists and the political world, especially Congress. One key to understanding the political world, in Turner's view, is the rewards system. Circumstances reward senators and representatives for pursuing reelection and for party loyalty because these are the routes to accomplishing the goals that led them to seek office. It is also important to understand the culture. The House of Representatives and the Senate, he noted, are "dominated by lawyers—the procedures and mores are lawyers' mores." Moreover, "a good story is what you need on Capitol Hill to win the debate." The committee system provides a way of involving specialists in the topics of legislation, but these people are "experts within the congressional framework." That means that "having more anecdotes" or stories based on evidence is a key to success. The Congressional Research Service was designed to be an in-house bridge to the science community, Turner noted. But, he added, "everybody is trying to influence them [senators and representatives]: lobbyists, the media, campaign contributors, constituents. They need to sort out within their value framework what truth is."

"How can SciSIP break in?" Turner wondered. He described a brochure on climate change he had seen that focused on changes the insurance industry will need to make to survive as the climate changes. It was well done, but no Ph.D. scientists were directly involved in preparing it. This would be an ideal SciSIP topic, he observed, but to influence policy makers, the SciSIP community will need stories based on social science research analysis to inform policy makers.

Finally, Turner noted, "this enterprise is data driven," and it is critical to focus on data sources of the 21st century, particularly big data. The separation of data from the physical world so that it can be manipulated in new ways "is almost a third revolution, after industrial," Turner concluded; "getting the right data and knowing how to use it will be the way to sharpen research and reach customers."

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Appendix A

SciSIP Principal Investigators' Conference

September 20-21, 2012

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The National Academy of Sciences
2101 Constitution Avenue, NW
Washington, DC 20418

Agenda

The two-day conference will facilitate scholarly exchanges between SciSIP principal investigators (PIs) and is intended to be the largest gathering of SciSIP principal investigators since the program's inception in 2006. Plenary sessions will feature path-breaking research by PIs, and presentations by prominent policymakers and researchers from the natural sciences and engineering (the activities which the PIs study); concurrent sessions will facilitate discussions among PIs on specific SciSIP research themes and methods. Poster and demonstration sessions will also provide opportunities for dialog between practitioners and researchers.

Topics to be addressed at the event will highlight advances in the emerging SciSIP field, including models, frameworks, tools, and datasets comprising the evidentiary basis for science and innovation policy. Presentations by SciSIP researchers will focus on several themes, such as: (1) Implementing Science Policy (includes the politics of science policy); (2) Scientific Discovery Processes; (3) Human Capital; (4) Organizations, Institutions, and Networks; (5) Innovation; (6) Data Extraction and Measurement; (7) Mapping Science; and (8) Assessment and Program Evaluation.
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DAY 1: Thursday, September 20, 2012, 8:45 a.m. – 5:30 p.m.

8:00–8:45 a.m. Registration (Main lobby entrance)

Poster Session Setup (West Court)

Breakfast available (Great Hall)

8:45–9:10 a.m. Welcome and Opening Remarks (Auditorium)

~ *Chair*: **Irwin Feller** (Steering Committee Chair)
~ *Speakers*:
Charles M. Vest (President, National Academy of Engineering)
Constance F. Citro (Director, Committee of National Statistics)
Myron P. Gutmann (National Science Foundation)

9:10–10:00 a.m. ROUNDTABLE: Science and Innovation Policymakers (Auditorium)

~ *Moderator*: **Al Teich** (George Washington University)
~ *Discussants*:
Sharon L. Hays (Computer Sciences Corporation)
Thomas Kalil (Office of Science and Technology Policy)
Joel Scheraga (U.S. Environmental Protection Agency)
William Colglazier (U.S. Department of State)

10:00–11:00 a.m. Plenary (Auditorium)

~ *Chair*: **Marie Thursby** (Steering Committee Member)
~ *Presenters*:
Erica Fuchs (Carnegie Mellon University); *On the Relationship Between Manufacturing and Innovation: Why Not All Technologies Are Created Equal*
Jason Owen-Smith (University of Michigan); *Selection, Access, and Use of Human Stem Cell Research Methods*
Chris Schunn (University of Pittsburgh); *Optimizing Example Distance to Improve Engineering Ideation*

11:00–11:30 a.m. Half-hour Break

Poster Session Presentations (West Court)

Refreshments available (Great Hall)

11:30–12:45 p.m. Concurrent Sessions A

I. Implementing Science Policy (Conference Room 120)

~ *Chair*: **Laurel Smith-Doerr** (Steering Committee Member)
~ *Presenters*:
Bruce Weinberg (Ohio State University) and **Subhra Saha** (Cleveland State University); *Estimating the Local Economic Spillovers from Science*
Scott Stern (Massachusetts Institute of Technology); *Exploring the Possibility, Utility, and Meaning of Lab-based Socio-technical Collaborations*
Jerry Thursby (Georgia Institute of Technology); *Communication, Collaboration, and Competition in Scientific Research*
Mathew Higgins (Georgia Institute of Technology); *Killing the Golden Goose: Accelerated Generic Entry and the Incentives for High-Risk Pharmaceutical R&D*

II. Scientific Discovery Processes (Conference Room 125)

~ *Chair*: **Chris Schunn** (University of Pittsburg)
~ *Presenters*:
Susannah Paletz (University of Pittsburgh); *Unpacking Social and Cognitive Processes in Science and Engineering Team Innovation*
Erik Fisher (Arizona State University); *Exploring the Possibility, Utility, and Meaning of Lab-based Socio-technical Collaborations*
Gary Bradshaw (Mississippi State University); *Science, the Little Bang, and Edison*
Jan Youtie (Georgia Institute of Technology); *Career-based Influences on Scientific Recognition in the United States and Europe: Longitudinal Evidence from Curriculum Vitae Data*

III. Human Capital (Members Room)

~ *Chair*: **Laure Haak** (ORCID)
~ *Presenters*:
Richard Freeman (Harvard University), **Wei Huang** (coauthor); *Collaborating With People Like Me: Study of Ethnic Composition of Scientific Teams in U.S.*
Rajshree Agarwal-Tronetti (University of Maryland) **and Jay Kesan** (University of Illinois); *Academia or Industry, Basic or Applied? Career Choices and Earnings Trajectories of Scientists*
Eric Stuen (University of Idaho); *Skilled Immigration and Innovation: Evidence from Enrolment Fluctuations in U.S. Doctoral Programmes*
Megan MacGarvie (Boston University); *Do Return Requirements Increase International Knowledge Diffusion? Evidence from the Fulbright Program*

12:45–2:15 p.m. Networking Lunch (Great Hall)

Poster Session Presentations (West Court)

~ *Poster presentations by:* **Margaret Clements; Sandy Dall'erba; Leslie DeChurch; James Evans; Bill Hadden; Jerry Hage; Myiah Hutchens, Alan Tomkins, and Lisa PytlikZillik; Luciano Kay; Martin Kenney; Anne Marie Knott; Greg Nemet; Bill Ribarsky, Wenwen Dou, and Yang Chen; Kenneth Simons; Laurel Smith-Doerr; Eric Stuen; Griffin Weber; Catherine Weinberger; Yilu Zhou; Nick Zolas**

SciSIP Program Research Visualization (West Court)

Demonstrations of Datasets and Tools (Auditorium)

~ *Chair*: **Greg Feist** (Steering Committee Member)
~ *Presenters*:
1:15 – 1:45 p.m. Lee Giles (Pennsylvania State University)
1:45 – 2:15 p.m. Lee Fleming (University of California, Berkeley)

2:15–3:10 p.m. ROUNDTABLE: Natural Scientists and Engineers (Auditorium)

~ *Moderator*: **Jim Turner** (Steering Committee Member)
~ *Speakers*:
M-H. Carolyn Nguyen (Microsoft Corporation)
Elizabeth Wilder (National Institutes of Health)
Jason Boehm (National Institute of Standards and Technology)

3:10–3:30 p.m. Twenty-minute Break

Poster Session Presentations (West Court)

Refreshments available (Great Hall)

3:30–4:45 p.m. Concurrent Sessions B

IV. Organizations, Institutions, and Networks (Conference Room 125)

~ *Chair*: **Erin Leahey** (University of Arizona)
~ *Presenters*:
Susan Cozzens (Georgia Institute of Technology); *U.S. Researchers in International Collaborations*
Kimberly TallBear (University of California, Berkeley); *Constituting Knowledge Across Cultures of Expertise and Tradition: Indigenous Bio-scientists*
Jerald Hage (University of Maryland); *Organizational Size and Its Discontents in Public Research Laboratories*
Ping Wang (University of Maryland); *Community Ecology for Information Technology Innovation*

V. Innovation (Conference Room 120)

~ *Chair*: **Ben Martin** (Steering Committee Member)
~ *Presenters*:
Lisa Cook (Michigan State University); *Are Patent Rights Needed for Invention and Innovation? Evidence from Soviet Experiments with the Market and Invention, 1959 to 1991*
Mark (Zak) Taylor (Georgia Institute of Technology); *Does Culture Matter for National Innovation Rates*
Bill Ribarsky (University of North Carolina at Charlotte)**;** *Analyzing the Impact of Science Funding Programs on the Evolution of Research Fields*

VI. Data Extraction and Measurement (Members Room)

~ *Chair*: **Bill Valdez** (Department of Energy)
~ *Presenters*:
Alan Porter (Georgia Institute of Technology) **and Ismael Rafols** (Georgia Institute of Technology); *Interdisciplinarity: Its Bibliometric Evaluation and Its Influence in Research Outputs*
Tim Sturgeon (Massachusetts Institute of Technology); *Survey of U.S. Firms on Their Global Value Chains and Domestic Jobs*
Iain Cockburn (Boston University); *Feasibility of a Quality-adjusted Price Index for Clinical Trials Research*
Daniel Sarewitz (Arizona State University); *Extracting and Assessing the Public Values of Science and Innovation Policies*

4:45–5:00 p.m. Fifteen-minute Transition Break

5:00–5:30 p.m. Wrap Up (Auditorium)

Irwin Feller (Steering Committee Chair)

5:30–5:45 p.m. Fifteen-minute Transition Break

5:45–7:30 p.m. Dinner; Buffet in the Great Hall

7:30 p.m. Planned Adjournment

DAY 2: Friday, September 21, 2012, 9:00 a.m. – 2:00 p.m.

8:00–9:00 a.m. Registration (Main lobby entrance)

Poster Session Setup (West Court)

Breakfast available (Great Hall)

9:00–10:00 a.m. Plenary: Measuring the Results of Science Investments (Auditorium)

~ *Chair*: **David Hart** (George Mason University)
~ *Presenters*:
Julia Lane (American Institutes for Research); *Big Data, Science Metrics, and the Black Box of Science Policy*
Asako Okamura (Japan Science and Technology Agency); *Towards the development of Science, Technology, and Innovation Policy: Challenges in Japan*

10:00–10:30 a.m. Half-hour Break

Poster Session Presentations (West Court)

Refreshments available (Great Hall)

10:30–11:45 p.m. Concurrent Sessions C

VII. Mapping Science (Conference Room 125)

~ *Chair*: **John King** (U.S. Department of Agriculture)
~ *Presenters*:
Zhen Lei (Pennsylvania State University); *Mapping Academic Patents to Papers*
Noah Feinstein (University of Wisconsin-Madison); *Who and When is Private? Exploring the Edges of Public-ness at an Interdisciplinary Research Institute*
Leah Nichols (National Science Foundation); *Applications of the NSF Portfolio Explorer: A Topic Model Approach to Portfolio Assessment*
David Newman (University of California, Irvine); *Using Topic Models to Measure Interdisciplinarity of Research Projects*

VIII. Assessment and Program Evaluation (Members Room)

~ *Chair*: **David Goldston** (Natural Resource Defense Council)
~ *Presenters*:
Amy Pienta (University of Michigan); *The Role of PI and Institutional Characteristics in Shaping Data Sharing Behavior*
Catherine Eckel (Texas A&M University); *Energy Policy for the Poor: An Assessment of Subsidized Weatherization Programs to Reduce Residential Energy Usage*
Jeff Furman (Boston University); *Retractions and Scientific Communities*

IX. Innovation (Conference Room 120)

Chair: **Ben Martin** (Steering Committee Member)
~ *Presenters*:
Maryann Feldman (University of North Carolina at Chapel Hill); *Accelerating Innovation: Venture Philanthropy as a New Research Funding Model*
Ryan Lampe (DePaul University); *Do Patent Pools Encourage Innovation? Evidence from 20 Industries under the New Deal*
Meg Blume-Kohout (University of New Mexico), **Krishna Kumar** and **Neeraj Sood** (coauthors); *Effects of Changes in Federal Funding on Academic R&D in the Biomedical Sciences*

11:45–12:00 p.m. Fifteen-minute Transition Break

12:00–12:30 p.m. Capstone Session (Auditorium)

Jim Turner (Steering Committee Member); *The Policy Relevance of SciSIP Output - Scientific Merit vs. Political Merit*

12:30–2:00 p.m. Lunch

Working lunch in **Great Hall**

2:00 p.m. Planned Adjournment

PARTICIPANT LIST[60]

Rajshree Agarwal-Tronetti, Department of Management and Organization, University of Maryland
Jeff Alexander, Center for Science, Technology, and Economic Development, SRI International
Gary Anderson, Office of the Director, National Institute of Standards and Technology
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Denise Baer, Boston University Washington Center
Daniel Basco, Science and Technology Policy Institute, Institute for Defense Analyses
Robert Bell, National Center for Science and Engineering Statistics, National Science Foundation
Chris Belter, Central Library, National Oceanic and Atmospheric Administration
Meg Blume-Kohout, Robert Wood Johnson Foundation Center for Health Policy, University of New Mexico
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[60]Affiliations are as of the time of the workshop.

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Jerry Hage, Center for Innovation, University of Maryland
Katherine Hale, National Center for Science and Engineering Statistics, National Science Foundation
Kara Hall, National Cancer Institute, National Institutes of Health
Dianne Hannemann, Office of Science Policy, Office of the Director, National Institutes of Health
David Hart, School of Public Policy at George Mason University
Sharon Hays, Office of Science and Engineering, Computer Sciences Corporation
Joseph Heppert, Office of the Vice Chancellor for Research & Graduate Studies, University of Kansas
Matthew Higgins, Scheller College of Business, Georgia Institute of Technology
Richard Hung, U.S. Government Accountability Office
Alan Hurd, Office of the Science and Technology Adviser to the Secretary, Department of State
Myiah Hutchens, College of Social and Behavioral Sciences, University of Arizona
John Jankowski, National Center for Science and Engineering Statistics, National Science Foundation
Brian Kahin, Sloan School of Management, Massachusetts Institute of Technology
Thomas Kalil, Deputy Director for Policy, Office of Science and Technology Policy
Amy Kaminski, Office of the Chief Scientist, National Aeronautics and Space Administration
Nirmala Kannankutty, National Center for Science and Engineering Statistics, National Science Foundation
Fumiyo Kaneko, Japan Society for the Promotion of Science
Luciano Kay, Center for Nanotechnology in Society, University of California, Santa Barbara
Kathryn Keeton, Science, Technology, and Engineering Group, National Aeronautics and Space Administration
Martin Kenney, Department of Human and Community Development, University of California, Davis

Jay Kesan, Program in Intellectual Property & Technology Law, University of Illinois at Urbana-Champaign
Heather Kimmel, Science & Technology Policy Fellow, American Association for the Advancement of Science
John King, Office of the Chief Scientist, U.S. Department of Agriculture
Anne Marie Knott, Olin Business School, Washington University in St. Louis
Hirokazu Koi, Center for Research and Development Strategy, Japan Science and Technology Agency
Kei Koizumi, Office of Science and Technology Policy
Kristen Koopman, Science and Technology Policy Institute, Institute for Defense Analyses
Jonathan Kramer, Maryland Sea Grant, University of Maryland
Ron Lai, Department of Computer Science, University of Chicago
Ryan Lampe, Driehaus College of Business, DePaul University
Joseph Lane, School of Public Health and Health Professions, University at Buffalo
Julia Lane, Senior Managing Economist, American Institutes for Research
Erin Leahey, Department of Sociology, University of Arizona
Israel Lederhendler, Office of the Director, National Institutes of Health
Zhen Lei, Department of Energy and Mineral Engineering, Penn State University
Joanna Lewis, Edmund A. Walsh School of Foreign Service, Georgetown University
Jennifer Lewis-Gallagher, Thomson Reuters
Megan MacGarvie, Boston University School of Management
Anthony Mann, Committee on National Statistics, The National Academies
Stephen Marcus, National Institute of General Medical Sciences, National Institutes of Health
Ben Martin, Science and Technology Policy Research, University of Sussex
Kate Maxwell, Research and Policy, Kauffman Foundation
Steve Merrill, Board on Science, Technology, and Economic Policy, The National Academies
Dorothy Miller, U.S. Environmental Protection Agency
Julia Milton, Consortium of Social Science Associations
Thema Monroe-White, Georgia Institute of Technology
Francisco Moris, National Center for Science and Engineering Statistics, National Science Foundation
James Morris-King, Computer Science, Auburn University
Peter Muhlberger, Texas Tech University
Steve Nelson, Science and Policy Programs, American Association for the Advancement of Science
Gregory Nemet, La Follette School of Public Affairs and Nelson Institute for Environmental Studies, University of Wisconsin-Madison
David Newman, Computer Science, University of California, Irvine
Leah Nichols, Social, Behavioral and Economic Sciences Directorate, National Science Foundation
Carolyn Nguyen, Technology Policy Group, Microsoft Corporation
Alexander Oetti, Scheller College of Business, Georgia Institute of Technology
Asako Okamura, Center for Research and Development Strategy, Japan Science and Technology Agency

Jason Owen-Smith, Department of Sociology and Organizational Studies Program, University of Michigan
Ozgur Ozmen, Industrial and Systems Engineering, Auburn University
Susannah Paletz, Learning Research and Development Center at the University of Pittsburgh
Gordon Phillips, Marshall School of Business, University of Southern California
Amy Pienta, Inter-university Consortium for Political and Social Research, University of Michigan
Alan Porter, Technology Policy & Assessment Center, Georgia Institute of Technology
Lisa PytlikZillig, Public Policy Center, University of Nebraska
David Rabson, College of Arts and Sciences, University of South Florida
Ismael Rafols, School of Public Policy, Georgia Institute of Technology
Steve Ramberg, Center for Technology & National Security Policy, National Defense University (NDU)
Andrew Reamer, GW Institute of Public Policy, The George Washington University
Angela Records, Eversole Associates
Andrew Reynolds, U.S. Department of State
Bill Ribarsky, College of Computing and Informatics, University of North Carolina at Charlotte
Emilda Rivers, National Center for Science and Engineering Statistics, National Science Foundation
Michael Roach, Kenan-Flagler Business School, University of North Carolina at Chapel Hill
Carol Robbins, Analysis and Special Studies Branch, Bureau of Economic Analysis
Rebecca Rosen
Joshua Rosenbloom, Associate Vice Chancellor for Research and Graduate Studies, University of Kansas
Philip Rubin, Haskins Laboratories, Yale University
Subhra Saha, College of Liberal Arts and Social Sciences, Cleveland State University
Daniel Sarewitz, Global Institute of Sustainability, Arizona State University
Joel Scheraga, Senior Advisor for Climate Adaptation, U.S. Environmental Protection Agency
Joshua Schnell, Analytics, Thomson Reuters
Christian Schunn, Learning Research and Development Center, University of Pittsburgh
Elaine Sedenberg, IDA Science and Technology Policy Institute
Stephanie Shipp, IDA Science and Technology Policy Institute
Mya Sjogren, Office of Research and Development, U.S. Environmental Protection Agency
Howard Silver, Executive Director, Consortium of Social Science Associations
Kenneth Simons, Department of Economics, Rensselaer Polytechnic Institute
Laurel Smith-Doerr, Department of Sociology, Boston University
Stacey Standridge, National Nanotechnology Coordination Office
Scott Stern, Sloan School, Massachusetts Institute of Technology
Miron Straf, Division of Behavioral and Social Sciences and Education, The National Academies
Eric Stuen, Department of Business, University of Idaho
Tim Sturgeon, Industrial Performance Center, Massachusetts Institute of Technology

Jia Sun, University of Maryland
Zoe Szajnfarber, Engineering Management and Systems Engineering, George Washington University
Kim TallBear, Department of Environmental Science, Policy, and Management, University of California, Berkeley
Mark Taylor, Sam Nunn School of International Affairs, Georgia Institute of Technology
Albert Teich, Center for International Science and Technology Policy, George Washington University
Alex Thompson, Environment, Science, and Innovation Group, Ministry of Business, Innovation, & Employment, New Zealand
Bonnie Thompson, Office of International Science and Engineering, National Science Foundation
Jerry Thursby, Strategic Management Faculty, Georgia Institute of Technology
Marie Thursby, Scheller College of Business, Georgia Institute of Technology
Alan Tomkins, Public Policy Center, University of Nebraska
Andrew Toole, Economic Research Service, U.S. Department of Agriculture
Vetle Torvik, Graduate School of Library and Information Science, University of Illinois at Urbana-Champaign
Jeff Tsao, Distinguished Member of Technical Staff, Sandia National Laboratories
Jim Turner, Association of Public and Land-grant Universities
Eskil Ullberg, George Mason University
Pavel Vaclavek, Control Board of TACR, Central European Institute of Technology
Bill Valdez, Office of Economic Impact and Diversity, U.S. Department of Energy
Walter Valdivia, Center for Technology Innovation Governance Studies, The Brookings Institution
Charles Vest, President, National Academy of Engineering
John Veysey, National Science Board Office, National Science Foundation
Matt Wallace, Science & Technology Branch, Environment Canada
Ping Wang, College of Information Studies, University of Maryland
Griffin Weber, Harvard Medical School
Bruce Weinberg, Department of Economics, Ohio State University
Catherine Weinberger, Department of Economics, University of California, Santa Barbara
Josh Whitford, Department of Sociology, Columbia University
Brad Wible, Senior Editor, *Science*
Elizabeth Wilder, Division of Strategic Coordination, Office of Portfolio Analysis and Strategic Initiatives, National Institutes of Health
Sharon Williams, Office of Science Management and Reporting, National Institutes of Health
Susan Winter, Office of Cyberinfrastructure, National Science Foundation
Levent Yilmaz, Samuel Ginn College of Engineering, Auburn University
Jan Youtie, Enterprise Innovation Institute, Georgia Institute of Technology
Ting Zhang, Jacob France Institute, University of Baltimore
Yilu Zhou, Department of Information Systems and Technology Management, George Washington University
Mark Zito, Office of Budget and Program Analysis, U.S. Department of Agriculture
Nick Zolas, U.S. Census Bureau

Appendix B

Lists of SciSIP Awards, 2007 through 2013

SciSIP AWARDS 2007[61]

A. Human Capital Development and the Collaborative Enterprise

1. Architecture of Collaboration in Transdisciplinary Research Teams (Barbara Gray and Raghu Garud, Pennsylvania State University)
2. Estimating the Effect of Exposure to Superstar Scientists: Evidence from Academia and the Biopharmaceutical Sector (Joshua Graff Zivin, NBER and Columbia University; Pierre Azoulay, MIT)
3. Measurement and Analysis of Highly Creative Research in the US and Europe (Philip Shapira, Juan Rogers, and Jan Youtie, Georgia Tech)
4. Social Network Analysis of the Collaborative Interaction of Scientists in Academic and Nonacademic Settings (Christopher McCarty, Nandita Basu, and James Jawitz, University of Florida)
5. Examining the Link between Informal Social Networks and Innovation: Using Netometrics to Quantify the Value of a Distributed Hetarchical Network (Leigh Jerome, Brooks B. Robinson-former PI, Martha Crosby, Laurel King, and Michael-Brian Ogawa, University of Hawaii)
6. Evaluation of Research Groups: An Endogenous Approach (Francisco Veloso, Carnegie Mellon University)

B. Returns to International Knowledge Flows

7. The Causal Impact of Foreign and Domestic Doctoral Students on Knowledge Creation and Innovation in US Universities: Evidence from Enrollment Shocks (Ahmed M. Mobarak and Keith Maskus, University of Colorado)
8. Contributions of Foreign Students to Knowledge Creation and Diffusion (Collaborative Proposal) (Shulamit B. Kahn, Boston University; Donna K. Ginther, University of Kansas)
9. Models of International Research Collaboration (Susan E. Cozzens and Marylin Brown, Georgia Tech)

[61] Institutional affiliations are listed as of the date the award was made to the researchers. Some of the researchers changed affiliations since receiving their SciSIP award. The summaries of presentations in the main part of this report list the current affiliation of the presenters at the conference.

C. Creativity and Innovation

10. Stimulating Creative Insight—A Cohesive Model of Design Innovation Across Individuals, Groups and Computer Agents (Jonathan Cagan and Kenneth Kotovsky, Carnegie Mellon University)
11. Design Tools to Cognitive Processes to Innovation (Christian D. Schunn and Michael Lovell, University of Pittsburgh)

D. Knowledge Production System

12. Developing the Science of Science and Innovation Policy: Profiles of Innovativeness and Gaps in the Idea Innovation Network (Jerald Hage and Jonathon Mote, University of Maryland)
13. Modeling the Dynamics of Technological Evolution (Doyne J. Farmer, William Brian Arthur, and Jessika Trancik, Santa Fe Institute; Douglas H. Erwin, US National Museum of Natural History; Walter W. Powell, Stanford University; as well as several senior collaborators)
14. Towards a Macroscope for Science Policy Decision Making (Katy Borner and Weixia Huang, Indiana University; Kevin Boyack, Sandia National Labs)
15. Research and Technology Partnerships: Quantifying Strategic Relationships (Nicholas S. Vonortas, George Washington University)

E. Science Policy Implications

16. Assessing the Impact of Science Policy on the Rate and Direction of Scientific Progress: Frontier Tools and Applications (Jeffrey Furman, NBER and Boston University; Fiona Murray, MIT; Scott Stern, Northwestern University)
17. Innovation and Technology Implementation: Theory and Policy Implications (Diego Comin, NBER and Harvard University; Bart Hobijn, New York University)
18. State Science Policies: Modeling Their Origins, Nature, Fit, and Effects on Local Universities (Maryann Feldman and James Hearn, University of Georgia)
19. Public Value Mapping: Developing a Non-Economic Model of the Social Value of Science and Innovation Policy (Daniel R. Sarewitz, Arizona State University; Barry Bozeman, University of Georgia)

SciSIP AWARDS 2008

A. Describing the Role of Firms in Innovation

1. The Division of Innovative Labor: Features, Determinants and Impacts on Innovative Performance (Ashish Arora, Carnegie Mellon; Wes Cohen, Duke University; John Walsh, Georgia Tech)
2. The Rise of International Coinvention: A New Phase in the Globalization of R&D? (Lee Branstetter, Carnegie Mellon University)
3. Modeling Innovation Chains Using Case-Based Econometrics (Kenneth Flamm,

University of Texas, Austin)
4. Patent Pools and Biomedical Innovation (Josh Lerner, NBER; Jean Tirole, Fondation Jean-Jacques Laffont/Toulouse Sciences Economiques)
5. Quantifying The Resilience of the U.S. Innovation Ecosystem (Erica Fuchs, Carnegie Mellon University)
6. The R&D “Lab” of the Future: Foundations for Modeling the R&D/Innovation Planning Process (Al Link, North Carolina State University; Mariann Jelinek, College of William and Mary)

B. Measuring and Tracking Innovation

7. Improving Productivity and Innovation Metrics: The Case of Financial Services (Carol Corrado, Janet Hao, and Bart Van Ark, The Conference Board; Charles Hulten, University of Maryland)
8. Linking Government R&D Investment, Science, Technology, Firms and Employment: Science & Technology Agents of Revolution (Star) Database (Lynne Zucker and Michael Darby, University of California, Los Angeles)

C. Measuring and Evaluating Scientific Progress

9. Measuring and Tracking Research Knowledge Integration and Transfer (Alan Porter, Georgia Tech)
10. Early prediction of the impact of research through large-scale analysis and modeling of citation dynamics (Marta Sales-Pardo, Northwestern University)
11. Universities, Innovation, and Economic Growth (Sheila Slaughter, University of Georgia)

D. Advancing Understanding of Collaboration and Creativity

12. A Social Network Database of Patent Co-Authorship to Investigate Collaborative Innovation and Its Economic Impact (Lee Fleming, Harvard University)
13. Modeling Productive Climates for Virtual Research Collaborations (Sara Kiesler, Carnegie Mellon University; Jonathon Cummings, Duke University)
14. Dynamics of Creativity and Innovation in Cyber-Enabled Scientific Commons (Levent Yilmaz, Auburn University)
15. OPEN PATENT: Modeling Tagging and Visualization Technologies to Enhance Comprehension of Patent Information (Beth Noveck, New York Law School; John Riedl, University of Minnesota)

E. Knowledge Sharing and Creativity

16. Integrating Social and Cognitive Elements of Discovery and Innovation (Chris Schunn, University of Pittsburgh)
17. Inspiration as Transmission of Creative Insight (Todd Thrash, College of William and Mary)
18. Transmission of Tacit Skills in East Asian Graduate Science Programs (Marcus

Antonius Ynalvez, Texas A&M International University; Noriko Hara, Indiana University)

F. Implementing Science Policy

19. Impacts of Institution-Level Policies on Science and Engineering Education, Employment, Earnings and Innovation: A "Natural" Experiment (Catherine J. Weinberger, University of California Santa Barbara)
20. Funding R&D when Ideas are Scarce (Suzanne Scotchmer, University of California-Berkeley)
21. University Research Parks and the Innovative Performance of Park Firms (Albert N. Link, University of North Carolina at Greensboro; Donald S. Siegel, University of California at Riverside)
22. Comparing Models for Integrating Societal Impacts Concerns into the Peer Review of Grant Proposals (Robert Frodeman, University of North Texas)
23. Scholar's Award Proposal for Investigating the Origins and Evolution of the "Basic Research" as a Political Symbol (Roger Pielke, University of Colorado)
24. A Political-Economic Model of Science and Innovation Policy (Mark Zachary Taylor, Georgia Tech)

SciSIP AWARDS 2009

A. Understanding Science and Innovation

1. A National Survey of Organizations to Study Globalization, Innovation and Employment (Clair Brown, University of California-Berkeley)
2. Tom Edison and the Electric Innovation Machine (Gary Bradshaw, Mississippi State University)
3. Science & Technology Innovation Concept Knowledge-base (STICK): Monitoring, Understanding, and Advancing the (R)Evolution of Science & Technology Innovations (PingWang, Yan Qu, and Ben Shneiderman, University of Maryland)

B. Modeling Innovation

4. A Predictive Simulation Model of Competitive Dynamics in Innovation (Risto Miikkulainen, University of Texas; Riitta Katila, Stanford University)
5. Modeling Schumpeter's Theory of Innovation as a Basis for Innovation Policy: An Experimental Approach (John Gero, George Mason University)
6. Co-Evolution of Innovative Products by Purposive Agents and the Growth of Technological Complexity (Robert Axtell and William Kennedy, George Mason University)
7. Firm Innovation, Selection and Labor Market Frictions (Rasmus Lentz, University of Wisconsin Madison)

C. Tracking Science and Innovation

8. Tracking Scientific Innovation from Usage Data: Models and Tools to Support a Science of Science (Johan Bollen, Los Alamos National Lab; Carl Bergstrom, University of Washington)
9. Assessing and Predicting Scientific Progress through Computational Language Understanding (James Evans, Ian Foster, and Andrey Rzhetsky, University of Chicago)

D. Scientific Networks and Science Outcomes

10. Mapping the International Evolution of Collaboration Networks on Patents Granted to Universities around the World (Margaret Clements, Indiana University)
11. The Influence of Network Structure on Sex Disparities in Scientific Collaboration: Commercial Innovation in the Life Sciences (KjerstenWhittington, Reed College)

E. Science and Innovation Policy

12. Compulsory Licensing - Evidence from the "Trading with the Enemy Act" (Petra Moser, Stanford University)
13. Metrics for Capturing Crucial Social Dynamics of Innovative Regions: Implications for S&T Policy (MaryWalshok, University of California San Diego)
14. Where Are All the Female Engineers? (Jeffery Smith, University of Michigan; Dan Black and Robert Michael, University of Chicago)
15. An Experimental Producer Price Index for Clinical Trials (Ernst Berndt, NBER; Ian Cockburn, Boston University)
16. Human Capital and Career Mobility in Science and Engineering-Intensive Start-ups: An Open Access Initial Public Offerings Database (Martin Kenney, University of California Davis)
17. Scientists and Engineers as Agents of Technological Progress: Measuring the Returns to R&D and the Economic Impact of Science and Engineering Workers (Richard Freeman, Erling Barth, Andrew Wang, and Gerald Marschke, NBER and Harvard University)

F. Describing Innovation

18. Applied Visual Analytics for Economic Decision-Making (David Ebert, Timothy Cason, David Hummels, and Anya Savikhin, Purdue University)
19. A Visual Analytics Approach to Science and Innovation Policy (Martin Ribarksy, Remco Chang, and Jim Yang, University of North Carolina at Charlotte)

SciSIP RAPID AWARDS 2009

A. Economy Wide Studies

1. Developing Real Time Metrics on the Effects of ARRA Investments on Technological Invention (Jose Lobo, Arizona State University; Deborah Strumsky, University of North Carolina at Charlotte)
2. A Study of the Economic Impacts of the 2009 U.S. Stimulus Package and Its Science Policies (Arnold Zellner, University of Chicago)
3. Testing a Metric and Evaluation System for Innovation Benefits (Jerald Hage, University of Maryland College Park)
4. Evaluating Impact of the 2009 American Recovery and Reinvestment Act on Social Science: An NSF RAPID Proposal (Amy Pienta, University of Michigan Ann Arbor)

B. Labor Market Specific Studies

5. Global Innovation and the Changing Nature of Domestic Engineering Work (Paul Leonardi, Northwestern University; Diane Bailey, University of Texas at Austin)
6. Federal Stimulus Funding for Research: An Assessment of Employment Responses (Sarah Turner, University of Virginia; John Bound, University of Michigan)
7. Assessing the Impact of Federal Stimulus R&D Funding on Employment and Scientific Output (Richard B. Freeman, NBER and Harvard University)

C. Agency Specific Studies

8. Advocating for an Inventive and Transformative Recovery in National STEM Education (Anthony E. Kelly, George Mason University)
9. The Impact of Stimulus Spending on Energy Efficiency in a Low-Income Dallas Neighborhood: Implications for Science Policy (James Murdoch, Rachel Croson, and Catherine Eckel, University of Texas at Dallas)
10. RAPID Study of Economic Stimulus on Local Government Energy Innovation and Collaboration (Richard C. Feiock, Florida State University)
11. Economic Stimulus and Innovation Capacity at the Department of Energy (Fred Block, University of California-Davis)

D. Non ARRA (American Recovery and Reinvestment Act) Rapid

12. From Bank to Bench to Breakthrough: Selection, Access, and Use of Human Stem Cell Research Methods (Jason Owen-Smith, University of Michigan Ann Arbor)

SciSIP AWARDS 2010

A. Adoption and Diffusion of Knowledge

1. Learning Across Product, Workgroup, and Geographic Boundaries (Erica R.H. Fuchs, Linda Argote, and Dennis N. Epple, Carnegie Mellon University)
2. Clusters, Heritage and the Microfoundations of Spillovers - Lessons from Semi-Conductors (Steven Klepper and Francisco Veloso, Carnegie Mellon University)
3. Specific, General, and Target Sharing of Information Among Academic Researchers (Marcie C. Thursby, Jerry G. Thursby, NBER)

B. Measuring and Tracking Science and Innovation

4. Innovation Personnel and Their Ecosystem: Career Choices and Trajectories of Scientists- Industry or Academia and Basic or Applied? (Rajshree Agarwal-Tronetti and Jay P. Kesan, University of Illinois Urbana-Champaign; Feniosky Pena-Mora, Columbia University)
5. Modeling Pharmaceutical Innovation Pipelines (Dissertation) (Kenneth Flamm and Alexandra Stone, University of Texas at Austin)
6. From Grant to Commercialization: An Integrated Demonstration Database which Permits Tracing, Assessing, and Measuring the Impact of Scientific Funding (Lee Fleming, Harvard University, and Vetle I. Torvik, University of Illinois at Urbana-Champaign)
7. Predictive Modeling of the Emergence and Development of Scientific Fields (David I Kaiser, David S. Jones, and Vincent A. Lepinay, MIT)

C. Advancing Understanding of Entrepreneurship and Innovation

8. Firm IQ: A Universal, Uniform and Reliable Measure of R&D Effectiveness (Anne Marie Knott, Washington University in St. Louis)
9. Personal Credit, New Firm Formation and Entrepreneurial Firm Growth (Gordon M. Phillips, NBER; Ethan Cohen-Cole, University of Maryland)
10. Technology Disruptions in Industries: Assessing Their Frequency, Processes, and Impact (Kenneth L. Simons, Rensselaer Polytechnic Institute)
11. Innovation and Growth of Human Social Organizations from Cities to Corporations (Geoffrey B. West, Santa Fe Institute; Luis Bettencourt, Los Alamos National Laboratory)

D. New Approaches to Studying Science and Innovation

12. Accelerating the Pace of Discovery by Changing the Peer Review Algorithm (Stefano Allesina, University of Chicago)
13. From Cycles to Spirals: Structural Analysis of Scientific Consensus Formation (Dissertation) (Peter S. Bearman and Uri Shwed, Columbia University)
14. Construct Utilization in the Behavioral Sciences (Kai R. Larsen and Jintae Lee, University of Colorado at Boulder; Eliot Rich, University at Albany)

15. New Methods to Enhance Our Understanding of the Diversity of Science (Andrew K. McCallum and Hanna M.Wallach, University of Massachusetts Amherst; Fiona Murray, MIT)
16. Developing a Social-Cognitive, Multilevel, Empirically-Based Model of Public Engagement for the Shaping of Science and Innovation Policy (Lisa M. Pytlik Zillig and Alan J. Tomkins, University of Nebraska-Lincoln; Peter Muhlberger, Texas Tech University)

E. Understanding the Impact of Structures and Processes on Science

17. Management and Organizational Practices Across the US (Nicholas Bloom, Stanford University; Erik Brynjolfsson, Massachusetts Institute of Technology; John Van Reenen, London School of Economics)
18. Toward a Theory of Innovation in Emerging Economies (Dan Breznitz, Georgia Tech)
19. Innovation in Social Networks (Nicole Immorlica, Northwestern University; Rachel E. Kranton, Duke University)
20. Bioethics Byplay? The Performances of Bioethics in the Private and Public Sectors (Dissertation) (Jason S. Robert and Jennifer E. Dyck Brian, Arizona State University.)
21. How Do Prizes Induce Innovation? Learning from the Google Lunar X-Prize (Dissertation) (Philip Shapira and Luciano Kay, Georgia Tech)
22. Scientific Knowledge Production for Solving Common Environmental Problems in a Developing Country (Dissertation) (David Winickoff and Javiera Barandiaran, University of California-Berkeley)

F. Implementing Science Policy

23. Information Values in Translation: An Ethnography of Free and Open Source Software in Vietnam (Dissertation) (Leah A Lievrouw and Nguyen Lilly, University of California Los Angeles)
24. Choosing a Portfolio of Technology Policies in an Uncertain World (Gregory F. Nemet, University of Wisconsin-Madison; Erin D. Baker, University of Massachusetts-Amherst)
25. The NIH Public Access Policy: Establishing a Basis for Assessing a Science Policy (John Willinsky, Stanford University)
26. Government Responses to Network Failures: The Case of the Manufacturing Extension Partnerships (Dissertation) (Joshua D. Whitford, Columbia University; Andrew Schrank, University of New Mexico)

SciSIP AWARDS 2012[62]

A. Adoption and Diffusion of Knowledge

1. Tracing Influence & Predicting Impact in Science (James Evans and Andrey Rzhetsky, University of Chicago)
2. The Long-Term Regional Economic Impacts from Public Investment in University Research (Shawn Kantor and Alex Whalley, NBER)
3. Organizations and the Diffusion of Scientific Knowledge (Scott Stern and Michael Bikard, MIT)
4. Incubators of Knowledge: Predicting Protégé Productivity and Impact on the Social Sciences (Cassidy Sugimoto, Ying Ding, and Stasa Milojevic, Indiana University)
5. The NIH Public Access Policy: Potential Impact on Physicians and Community Health Organizations (John Willinsky, Stanford University)

B. Understanding the Impact of Structures/Process on Science

6. The Evolving Research Enterprise (Maryann Feldman and Michael Roach, University of North Carolina at Chapel Hill)
7. Managing Community: The Organization and Management of Federal Research Funding Agencies (Michael Piore, MIT)
8. What Model for Public-Private Partnerships? Lessons from Existing Consortia for Administration of the U.S. National Network for Manufacturing Innovation (Erica Fuchs and David Hounshell, Carnegie Mellon University)
9. A Comparative Study of Structural Influences on User-Engaged Ecology Research (Mark Neff, Allegheny College)
10. ICES-GMU Workshop on Internationalization & Competitiveness (Eskil Ullberg and Daniel Houser, George Mason University)
11. Empirical Studies of Innovation in Health Care Markets (Heidi Williams, NBER)

C. Advancing Understanding of Entrepreneurship and Innovation

12. Atlanta Competitive Advantage Conference PhD Student Workshop (William Bogner, Georgia State University)
13. Inter-Industry Differences in the Antecedents and Consequences of Industrial Scientists Mobility and Entrepreneurship Decisions (Rajshree Agarwall-Tronetti and Seth Carnahan, University of Maryland College Park; Martin Ganco, University of Minnesota-Twin Cities; Benjamin Campbell, Ohio State University)

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[62]In 2012, SciSIP program directors began documenting abstracts according to the year the awards were issued (the fiscal year) instead of the year of the solicitation and panel review. Therefore, these 2012 awards were reviewed by the SciSIP panel in 2011, and the 2013 awards were reviewed by the SciSIP panel in 2012. SciSIP proposal competitions occurred every year since the first solicitation in 2007.

D. New Approaches to Studying Science and Innovation

14. Understanding Innovative Science: The Case of the Wisconsin Institutes for Discovery (Daniel Kleinman, Gregory Downey, and Noah Feinstein, University of Wisconsin Madison)
15. Evaluating the Effect of Cyberinfrastructure on Universities' Production Process (Amy Apon, Linh Ngo, and Paul Wilson, Clemson University)
16. Sensible Science: A Sociometric Approach to Collaboration in Synthesis Groups (Edward Hackett, Arizona State University)
17. Incentives for Researcher Profile Maintenance and Access, and Their Value in Science and Innovation (Erik Lium, Claire Brindis, Mini Kahlon, and Tuhin Sinha, University of California San Francisco; Ian Foster, University of Chicago)
18. Scientific Collaboration in Time (Carl Lagoze, University of Michigan-Ann Arbor, and Steven Jackson, Cornell University)

E. Implementing Science Policy

19. Science of Science and Innovation Policy: Principal Investigator Conference, 2007-2011 Awards (Kaye Husbands Fealing, National Academy of Sciences)
20. Balancing the Portfolio: Efficiency and Productivity of Federal Biomedical R&D Funding (Margaret Blume-Kohout, University of New Mexico, and David Newman, University of California-Irvine)
21. Effects of Immigrant Scientists and IPRS on Innovation (Petra Moser, NBER)
22. Estimating the Economic and Scientific Impact of Federal R&D Spending by Universities (Jason Owen-Smith and Margaret Levenstein, University of Michigan-Ann Arbor)
23. Collaborative Research: Women in Science and Technology Policy (Kaye Husbands Fealing, Jennifer Kuzma, Debra Fitzpatrick, University of Minnesota; Susan Cozzens (Georgia Tech); Laurel Smith-Doerr (Boston University)
24. 2012 Science and Technology Policy Gordon Research Seminar (Susan Cozzens and Nancy Gray, Gordon Research Conferences)

F. Measuring and Tracking Science and Innovation

25. Using Researcher Profiles to Demonstrate the Impact of Investments in Science (Griffin Weber, Harvard University)
26. Connecting Outcome Measures of Entrepreneurship, Technology, and Science (COMETS) (Lynne Zucker and Michael Darby, NBER)
27. The Impact of Research and Development on Quality, Productivity, and Welfare (Amil Petrin, University of Minnesota Twin Cities)
28. Career Dynamics in the Science and Engineering Workforce (Catherine Weinberger, University of California-Santa Barbara)
29. Investing in Science, Research and Technology: Where Is the Biggest Bang for the Buck? (Sandy Dall'erba and Jaewon Lim, University of Arizona)

SciSIP AWARDS 2013

A. Adoption and Diffusion of Knowledge

1. CAREER: Empirical Studies of Technology Adoption (Pascaline Dupas, Stanford University)
2. Doctoral Dissertation: Innovation by Users in Emerging Economies and Impacts on Innovation Policy: Evidence from Mobile Bank (Serguey Braguinsky and Paul van der Boor, Carnegie Mellon University)
3. Drivers and Effects of Technology Adoption (Diego Comin, NBER)
4. The Initial Career Transitions of Science & Engineering PhDs (Henry Sauermann, Georgia Tech)

B. Understanding the Impact of Structures/Process on Science

5. CAREER: Incentives, Diversity, and Scientific Problem Choice (Kevin Zollman, Carnegie Mellon University)
6. Collaborative Research: BRIDGES: Building Resources through Integrating Disciplines for Group Effectiveness in Science (Theresa Lant, Pace University; Maritza Salazar, Claremont Graduate University)
7. Collaborative Research: Multi-Team System Design for Maximizing Scientific, Technological, & Policy Innovation (Stephen Zaccaro, George Mason University; Lorelei Crerar, George Mason University; Leslie DeChurch and Ruth Kanfer, Georgia Tech)
8. Collaborative Research: Technology, Collaboration, and Learning: Modeling Complex International Innovation Partnerships (Danielle Wood, Johns Hopkins University; Dava Newman, MIT)
9. Contracting for Innovation: The Governance of University-Industry Partnerships (Steven Casper, Keck Graduate Institute)
10. Doctoral Dissertation: A Global Partnership Approach to Clean Energy Technology Innovation: Carbon Capture and Storage (David Sonnenfeld and Xiaoliang Yang, SUNY College of Environmental Science and Forestry)
11. International Partnerships and Technological Leapfrogging in China’s Clean Energy Sector (Joanna Lewis, Georgetown University)
12. The Executive Science Network: University Trustees and the Organization of University Industry Exchanges (Sheila Slaughter, University of Georgia)

C. Advancing Understanding of Entrepreneurship and Innovation

13. Circling the Triangle: Understanding Dynamic Regional Economies (Maryann Feldman, and Nichola Lowe, University of North Carolina)

D. New Approaches to Studying Science and Innovation

14. EAGER: Understanding Technological Change from the Map of Capabilities (HyeJin Youn, Santa Fe Institute; Aaron Clauset, University of Colorado)

15. Expanding Understanding of the Innovation Process: R&D and Non-R&D Innovation (John Walsh, Georgia Tech)
16. Research Development Workshop - Atlanta Competitive Advantage Conference 2013- 2015 (William Bogner, Georgia State University)

E. Implementing Science Policy

17. A Transdisciplinary Deliberative Model for Just Research and Policy: Toward Resolving The Crisis of Vanishing Insect Pollinators (Daniel Kleinman, University of Wisconsin-Madison)
18. Advancing Behavioral and Social Science Research for Public Policy: The Policy Roundtable of the Behavioral and Social Sciences (Miron Straf, National Academy of Sciences)
19. Credibility and Use of Scientific and Technical Information in Science Policy Making: An Analysis of the Information Bases of the National Research Council's Committee Reports (Barry Bozeman, Arizona State University; Jan Youtie, Georgia Tech; Jeffrey Wenger, University of Georgia)
20. ENGAGE - Behavioral responses to advanced energy metering technology: A large scale experiment (Magali Delmas, William Kaiser, and Noah Goldstein, University of California-Los Angeles)
21. Innovation in an Aging Society (NIH co-funded project) (Bruce Weinberg, The Ohio State University; Gerald Marschke, University of California-Davis; Subhra Saha, Cleveland State University)

F. Measuring and Tracking Science and Innovation

22. Building Community and a New Data Infrastructure for Science Policy (Jason Owen-Smith, University of Michigan; Julia Lane, American Institutes of Research; Margaret Levenstein, University of Michigan)
23. Discovering Collaboration Network Structures and Dynamics in Big Data (Jian Qin, Jeffrey Stanton, and Jun Wang, Syracuse University)
24. Planning Meeting on Indicators of Doctoral Education (Connie Citro, National Academy of Sciences)
25. Small Business Programs, Innovation, and Growth: Estimating Policy Effects Using Comprehensive Firm-Level Panel Data (John Earle, George Mason University)
26. The Biographies of Scientific Ideas: What the Content and Structure of Citations Reveal About the Diffusion of Knowledge (Freda Lynn, University of Iowa; Michael Sauder, University of Iowa)

COMMITTEE ON NATIONAL STATISTICS

The Committee on National Statistics was established in 1972 at the National Academies to improve the statistical methods and information on which public policy decisions are based. The committee carries out studies, workshops, and other activities to foster better measures and fuller understanding of the economy, the environment, public health, crime, education, immigration, poverty, welfare, and other public policy issues. It also evaluates ongoing statistical programs and tracks the statistical policy and coordinating activities of the federal government, serving a unique role at the intersection of statistics and public policy. The committee's work is supported by a consortium of federal agencies through a National Science Foundation grant.