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Advancing Measures of Innovation

Knowledge Flows, Business Metrics, and Measurement Strategies
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Any opinions, findings, conclusions, or recommendations expressed in this workshop report are those of the participants and do not necessarily reflect the views of the National Science Foundation.

Executive Summary

The workshop "Advancing Measures of Innovation" was driven by recent calls for improvements in statistics on research and development (R&D) and innovation, in order to better serve policy needs, advance research on the nature and impact of innovation, and, more broadly, help develop the field of Science of Science Policy.

The workshop brought together participants from both the research and the federal statistical communities to examine new or little known innovation-related data and research and to discuss data development priorities and strategies. Participants set the stage by examining current research challenges and innovation theory and considering the interplay of metrics, research, and analysis and policy. The workshop then went on to address two key questions for the future: Which metrics are most urgent or immediately feasible? What statistical and research activities are likely to advance these priority metrics?

Workshop discussions made clear the continued need for research related to innovation, including inputs to and components or stages of the innovation process, outputs and outcomes, and the social returns of innovation. There was a strong sense that research is currently impeded by several limitations: insufficient data, underutilization of existing data, and insufficient linkage among and integration of existing datasets.

Workshop participants variously discussed the kinds of data that merit greater attention and integration in order to advance our understanding of innovation. These include science and engineering employment and mobility data, international economic data, data on university-industry cooperation, and data collected by industries and firms for their own purposes. The workshop also highlighted the need for closer interaction between researchers and innovators (individuals and firms) as well as among researchers, statistical agencies, and policy makers concerned with innovation.

Workshop participants discussed a number of strategies for data development. These included survey-based methods, including comprehensive innovation surveys; data linking and data integration; nonsurvey-based methods (such as mining of administrative data); and using case studies and qualitative data. This last approach can be especially useful for early identification of trends and structural changes. The sense of the workshop is that the diverse strategies are not mutually exclusive and can be pursued productively in parallel or in combination. Discussants eschewed setting priorities among various approaches, implying that, at this stage, opportunities to advance research on innovation abound and considerable gains are likely to result from any and all the approaches discussed. To some extent, the optimal mix of options will be determined by policy and research needs, resource availability, and the particular risks and benefits inherent in each approach.

The agenda and presentations from this workshop are available at http://www.nsf.gov/statistics/workshop/innovation06/. Workshop papers, along with additional papers consistent with workshop objectives, will be published in a special issue of the *Journal of Technology Transfer*.

Introduction

Background and Workshop Objectives

The National Science Foundation's Division of Science Resources Statistics (NSF/SRS) held the workshop Advancing Measures of Innovation on June 6–7, 2006. The workshop was driven by three main considerations. First, the call by John H. Marburger III, the President's science and technology adviser, for better data, models, and tools for understanding the U.S. scientific and engineering enterprise in its global context by advancing the nascent field of science of science policy. Second, the National Academies' Committee on National Statistics (CNSTAT) study on *Measuring Research and Development Expenditures in the U.S. Economy*,**[1]** which recommended that SRS "explore the impact of innovation on the U.S. economy" and initiate a "program of measurement and research related to innovation." Third, activities leading to Blue Sky II, an international conference organized by the Organisation for Economic Co-operation and Development's (OECD) Group of National Experts on Science and Technology Indicators (NESTI), which was held in late September 2006 in Ottawa, Canada, to discuss the development of new and better indicators of science, technology, and innovation.

Accordingly, the workshop set forth a number of objectives and key questions. The short-term objectives were to examine new or little known innovation-related data and research and to explore data development priorities and strategies: policy context, resources, and constraints (business, research, and statistical communities). The long-term objectives were to promote interdisciplinary work on data development from multiple sources, contribute to empirical research on innovation activities and outcomes, and contribute to science of science policy efforts across federal agencies and beyond.

Two key questions were posed to the participants with respect to data development priorities and strategies:

- Based on workshop discussions, which metrics stand out as most urgent and/or are most immediately feasible?
- Which statistical and research activities are likely to advance these priority metrics?

Organization of the Report

This report summarizes the main themes discussed at the workshop. Considerable discussion was devoted to data needs and data development strategies. Because data needs often derive from the research or policy questions one is trying to answer, the discussion also covered these topics. The first section of the report serves to set the stage for the subject of innovation metrics, and the second covers the main contributions of the workshop.

Footnotes

[1] L.D. Brown, T.J. Plewes, and M.A. Gerstein, Eds. 2005. *Measuring Research and Development Expenditures in the U.S. Economy*. National Academies Press: Washington, DC.

Setting the Stage for Innovation Metrics Development

Research Challenges

Innovation research seeks to understand the sources, mechanisms, and effects of innovation and technological change and to measure its inputs (people and the training they receive, physical and financial resources, and how they change over time). It is also important to understand the intermediate products of the process of technological innovation, such as knowledge spillovers and research tools. Outputs (e.g., scientific papers that directly result from projects or programs) and outcomes (broader social impacts, such as improved productivity, income, and well-being) are also important to understand. From an economic viewpoint, spillover—social returns to innovation in excess of the private returns—may be the most important research topic because, in many cases, it is the basis for public policy.

Part of the workshop discussion centered on improved understanding of what is happening at different stages of the innovation process. It was generally agreed that the innovation process can be characterized as complex and nonlinear. In this context, there remain identifiable players and activities that need intense study and data development on such topics as activities of firms working at different stages of innovation and links between firms and universities at different levels of aggregation. Many research and policy questions require data at less-aggregated levels, such as the industry or firm level, than do broad, national-level indicators. Several analysts expressed an interest in gaining insight into public-private partnerships.

Scholars who study different parts of the innovation system have different data needs. There is little consensus on what to measure at each level and each stage of innovation, how to measure it, how often to measure it, or what would be an appropriate point of comparison. There was discussion about the definition of innovation, ranging from a comment that innovation occurs when a new product is first sold, to considering innovation as a new way of doing something even if it does not put a new product on the shelf. For example, improvements in services and designs can be innovative and enhance productivity and should also be considered innovation. This is part of the set of questions that participants thought should be addressed by NSF-supported research—considering what constitutes innovation.

There was a sense at the workshop that innovation research is constrained by data limitations. The problem may not be only the lack of data, but also the underutilization of data, the lack of connection between the data available and the problems to be solved, and the difficulty of linking existing datasets. For example, if it is desirable to link R&D surveys to data or surveys on innovation and diffusion so that researchers can follow product development through the stages of R&D and innovation, these surveys and databases should be designed with potential links in mind.

Activities that are not traditionally thought of as part of the innovation system may actually contribute a great deal to the innovation process. Technical services, industrial designs, quality assessment, and training are all part of the innovation process, but these activities are not fully integrated into existing theory or models, and little, if any, data are available for them.

Companies have very different ways of thinking about metrics and defining innovation. Because firms are at the forefront of innovation, researchers would benefit from working more closely with firms to determine how they define innovation, research, and productivity. Can innovation metrics used by industry be scaled up for use as national-level indicators, or do they suggest sector-level indicators? Conversely, what kind of innovation metrics do firms need from government? What might be an optimal mix of government and industry roles in the development of data on innovation?

Research questions raised in workshop discussions included the following:

- Is open or collaborative innovation now occurring at a significant level and are the different institutional forms associated with it becoming manifest?
- Are incumbents or outsider firms more likely to introduce radical product innovations?
- What is driving the growth in university licensing?
- What is the extent of knowledge spillovers from university to industry?
- What motivates firms to invest in R&D?
- What kind of businesses adopt advanced technologies?
- To what extent is U.S. industry moving its R&D abroad? And, to what extent are foreign firms bringing R&D to the United States?
- What factors affect multinational corporations locating R&D outside the home country?
- Why do some research joint ventures fail while others succeed?
- Are firms located in a research park more research-productive? Do returns vary by type of park?

Innovation Theory Needs

Although the workshop discussion focused primarily on data needs, there was also recognition of the need for new or improved models, theories, or conceptual frameworks. Theories are needed to interpret the data; theories can also suggest the kinds of data that need to be collected.

Marburger has challenged the science policy research community to generate new and better indicators and models in support of a new science of science policy. Some workshop participants discussed the relative merits of multiple models addressing different sectors or policy objectives.

There was discussion about the development of a general equilibrium model based on existing endogenous models of economic growth. Such a model would sew together disparate evidence and would allow policy experiments. The model would be tightly linked to evidence from microeconometric studies on R&D and technological change. The aim would be to accumulate the wisdom from an ever-expanding set of empirical studies into a unified whole. The model would speak to firm-level evidence, but would also aggregate up to the economy-wide level, with an international dimension. One could use it to give advice on formulating R&D policy. When an input is changed, the model would show what would happen. The model should embody international trade and technology diffusion. As more and better data are assembled, the agenda of developing a general equilibrium model seems more realistic.

Developing a set of logic models for different innovation mechanisms (such as partnerships or grants), like the logic modeling done for program evaluations, was another approach discussed. Logic models could reveal the key research questions and what is known relevant to those questions for the various mechanisms. This approach might make research results more understandable and useful to policy makers.

It was pointed out that industrial R&D firms have developed the Technology Value Pyramid, a conceptual framework that links innovation investments with important outcomes, such as increases in shareholder value, in a way that managers can influence. It was suggested that something like this might be developed at the federal level. It was also observed that the broad range of social, economic, behavioral, and cognitive sciences collectively can inform the development of innovation models and suggest what kinds of data should be collected. For example if researchers can understand the cognitive dimensions of how scientists come up with innovations, it may be possible to fit that into innovation models. One participant noted specifically that "a healthy dose of interaction of data and models—that is, a mix of inductive and deductive approaches is very useful."

Examples of Policy Issues to be Addressed by Research

Ultimately, it is the policy-making community that will define the issues that the science of science policy should address. That said, on the basis of current experience, workshop participants mentioned a number of issues that have served as a backdrop to their research on innovation. They include the following:

- Does innovation occurring in other countries threaten the continued ability of the United States to compete economically?
- What are the extent and possible effects of the flow of U.S.-educated foreign-born scientists and engineers returning to their home countries?
- How can nanotechnology be fostered in various U.S. regions?
- What are the implications of global R&D flows? Should it be encouraged or discouraged?
- How does the Research and Experimentation Tax Credit affect the level of R&D performed by companies?

Other key policy-research areas were mentioned. These include studying/measuring the difference between manufacturing and nonmanufacturing in terms of employment and their R&D intensity and determining whether U.S. and overseas innovation are substitutes or complements.

Innovation Data, Analysis, and Policy

The issue of how innovation data and analysis relate to policy was discussed. Some workshop participants expressed concern that there is, at best, a very weak connection between innovation studies and analyses and the questions that policy-makers concerned with innovation confront. Although research has steadily increased our knowledge about innovation, what has been learned is, by and large, not informing policy. For example, for some participants the relationship between relevant research findings and recent policy proposals in the areas of research joint ventures and science parks was unclear. In the absence of systematic research findings, public policy tends to rest on "common wisdom." However, as pointed out more than once at the workshop, research on innovation often shows common wisdom to be wrong.

It was noted that the challenge is to make innovation research inform policy better, while maintaining its independence and objectivity. Researchers can fruitfully focus on specific questions of interest to policy makers, but the research community should articulate clearly which questions can be answered in the near term and which cannot.

The research community should lay out a realistic set of expectations for the science of science policy.

Advancing Measures of Innovation

Two key questions were raised at the outset of the workshop.

Which indicators are most urgent?—In answer to this question, a number of indicators were mentioned as being urgently needed, although no consensus was established on priorities among them.

Which indicators are most immediately feasible?—Workshop participants emphasized that measuring innovation poses difficult problems but is important to do. The workshop discussion did not produce an explicit assessment of which indicators are most immediately feasible. However, there was a sense that additional analysis of existing indicators and linking existing indicators were more immediately feasible than developing indicators that depend on developing new or revised surveys or datasets.

Innovation-Related Data and Research

Several presenters described new or little-known innovation-related data and research. These are grouped into five categories, listed below.

1. Scientific and Technical (S&T) Employment

S&T employment statistics are important because they measure the human resource input to R&D and innovation. The importance of human resources to innovation is increasingly recognized. The Bureau of Labor Statistics (BLS) has employment data broken out by occupation and by industry. There is a sense that these data have not been used as much as they could be in the study of innovation, as discussed by one workshop participant.

As noted by another presenter, much of the knowledge produced by R&D is "wrapped up" in individuals and moves with them. This presenter had worked with the NSF Survey of Earned Doctorates (SED) to code the industrial placement information on the SED, which had never been done before. She noted that human resource data may complement R&D expenditure data in some ways, showing either more or less innovation activity than might be shown by R&D expenditures under different circumstances. She stated that human resource data could be even more useful if they included the following enhancements:

- collecting follow-up data on the activities of those PhDs without definite post-graduation plans at degree completion
- learning about placements of postdoctoral researchers with industry
- obtaining salary information for new placements
- extending the data set to include additional post-dot.com years
- linking the data with productivity measures

2. International Economic Data

It may not be widely recognized that the international data collected by the Bureau of Economic Analysis (BEA) include innovation-related data. As innovation activity becomes increasingly diffused around the globe, international data become more important to understanding the U.S. position. One speaker highlighted several series of innovation-related statistics collected by BEA, as follows:

- international services exports and imports, including royalties and license fees and research, development, and testing services

- sales of services through affiliates of multinational corporations (MNCs), including scientific research and development services
- R&D activity of MNCs, including R&D spending and employment

Another speaker commented that it is interesting that data exist for international commercial transactions among MNCs but not for domestic transactions. Some private companies reportedly have this kind of data, but the data are of uncertain quality.

3. Federal Trade Commission Database on R&D

The Federal Trade Commission at one time published a line-of-business database that had R&D data broken down by SIC (standard industrial classification code). These data exist for 1974–77 and have been used in research by some of the workshop participants.

4. Industrial Research Institute R&D Survey

The Industrial Research Institute surveyed R&D at member firms from 1991 to 1999. Data were collected at both the firm level and the line-of-business level. Data were included for some output variables, such as patents, new sales ratio (revenues realized this year from new products introduced in the last 5 years divided by total revenues realized this year), and cost savings realized (cost savings realized this year from process improvements made in the last 5 years divided by gross profits realized this year). There are 27 directly measured metrics. In addition, 16 computed metrics can be derived and 10 more metrics can be obtained through clustering. The results of this survey were reported annually in *Research-Technology Management* between 1993 and 1999. The data file is maintained and available through the Center for Innovation Management Studies at North Carolina State University.

5. University-Industry Knowledge Flows

One speaker provided a list of data sets used in research on university-industry knowledge flows, noting that the burgeoning literature on this topic is highly interdisciplinary, uses proprietary databases and a wide variety of performance indicators, makes use of both quantitative and qualitative methods, and performs analyses at numerous levels of aggregation. Data sources include the following:

- databases developed fully or in part with NSF support, including the COoperative REsearch (CORE) and the National Cooperative Research ActResearch Joint Ventures (NCRA-RJV) databases, both based on companies' research joint-venture filings with the Department of Justice, and MERIT-CATI (Maastricht Economic Research Institute on Innovation and Technology-Cooperative Agreements & Technology Indicators)
- Association of University Technology Managers (AUTM) survey of U.S. universities
- Nottingham University Business School (NUBS)/University Companies Association (UNICO) survey of UK universities' technology transfer offices
- Yale and Carnegie Mellon surveys of R&D managers
- proprietary databases, such as those of Compustat, Dun and Bradstreet, Recombinant Capital, Science Citation Index, Thomson Financial (SDC, Securities Data Company), and Venture Economics

One speaker further noted that many of the proprietary data sets cover embryonic industries, such as the nanotechnology industry, whereas official statistics tend to be collected after a new phenomenon is well established. He indicated that the Yale and Carnegie Mellon surveys of R&D managers are some of the more creative surveys and suggested that this is because researchers were involved in their design. Those surveys may provide a model for other data-collection efforts.

Data Needs

The workshop participants identified a number of data needs focused on different aspects of and results from the innovation process. These are grouped in 11 categories, listed below.

1. Innovative Activities

These activities include R&D, R&D support, and the steps that need to be taken between R&D and the introduction of a new product or concept into the market or into large-scale use. These steps may include pilot plant and start-up manufacturing.

- diffusion and adoption of innovations, including the diffusion of ideas and other innovation-related intangibles, such as new business practices, broadband Internet, or evidence-based medicine
- innovation activities that take place outside the R&D laboratory, since many small, innovative firms do not have R&D laboratories
- R&D gestation lag from concept to innovation
- radical compared with incremental innovation

2. Key Drivers, Inputs, and Institutional Mechanisms

Data needs associated with this topic include the following:

- R&D spending decisions (levels, organization, focus, geographic location, integration with organizational objectives), human resources needs, equipment, facilities, and infrastructure
- coinvestments with R&D, such as training, marketing, advertising, and brand management; complementary capabilities that allow firms to take advantage of their R&D include organizational methods, manufacturing, and distribution
- economic drivers, such as profit potential or policy and social needs, and the role of industry and market structure
- market demand compared with technological opportunity, such as knowledge going to firms originating in universities or rivals (the latter is where the vitality of the underlying science, technology practice, and cumulative knowledge come into play; the relative weight of these factors raises issues of technology management and commercialization including patenting, secrecy, and first-mover advantage)
- key institutional players in innovation, such as multinational corporations, small and large businesses, startups, and universities
- new institutional mechanisms that may promote innovation, such as research joint ventures and research parks
- stocks of knowledge—the cumulative stock of previous inputs for intermediate products
- management of R&D, technology, and innovation; entrepreneurship; and knowledge management

- the role of uncertainty and risk in innovation, and financing during different stages of innovation
- culture and attitudes toward innovation (both by individuals and by businesses and other social organizations)

3. Outputs and Outcomes of Innovation

Outputs are the immediate results of innovation, such as new and improved products, processes, services, business models, and business practices. Some outputs, such as publications and patents, are intermediate outputs and may be inputs at later stages of the process. Outcomes refer to the impacts (positive and sometimes negative) of innovation. These include the following:

- private impacts (impacts on the innovating organization) and public or social impacts (impacts on others outside the innovating organization); different private and public impacts may arise from a given innovation because of the phenomena of spillover, technology transfer, licensing of technology and patents, and innovation diffusion
- micro impacts (impacts on individual persons and institutions) or macro impacts (impacts on the nation as a whole)
- changes in industrial productivity, national competitiveness, or social welfare

These outcomes are in part behind the rationale for government to support innovation and technology. The difficulty of measuring outcomes and attributing them to investments in innovation, due to long time lags for example, was also discussed.

4. Effects of Government Policies on Innovation

Data needs associated with this topic include the following:

- data for use in program evaluations and to address such questions as whether the R&D tax credit program stimulates additional R&D spending by private firms
- data on indirect consequences of government policies, such as regulations of various types

5. Relationships, Knowledge Flows, and Networks

Data needs associated with this topic include the following:

- data to assess the role of supply chain, business alliances, contractors, and customer services in innovation strategies, technology codevelopment, and commercialization, both domestically and globally
- role of public science/public knowledge; informal flows of information (e.g., nonpatented inventions)
- role of technical and engineering services in innovation
- data to track spillovers from universities to firms
- data on the movement of scientists, engineers, new PhDs, and other technical personnel across institutions, sectors, and countries.

6. Accounting for Innovation and Its Relationship to Finances

Data needs associated with this topic include the following:

- intangible assets accounting
- R&D output price deflator to construct constant price data
- R&D gestation lag to account for time value of money
- depreciation rate for both income statement and balance sheet

7. Adoption and Diffusion of Innovations

The adoption and diffusion of innovation need to be given much more prominence. Diffusion is really important because that is how most returns to innovation are realized, and particularly at the micro level, this has not been well studied. Attention should be focused not just on technology diffusion but also on diffusion of new practices, such as the broadband Internet or evidence-based medicine. Broad surveys may be too ambitious, but specialized surveys or case studies may be appropriate.

8. Mobility of Individual Scientists and Graduate Students

The phenomenon of midcareer mobility will become a bigger issue for the United States. And it is important to pay attention to the mobility of individual scientists and graduate students. Human resource data illuminate patterns of innovation not emphasized by R&D data. R&D data are generally characterized by the following:

- not generally available at the city level
- collected at the corporate level, not at the plant level where much of the research is being done
- may miss innovative activities that occur in the service sector and non-laboratory sector of manufacturing firms

9. Intangibles and Disembodied Knowledge

Discussions made it clear that knowledge should be thought of as both embodied (e.g., new goods) and disembodied (e.g., scientific publications), and both need to be tracked. Intangibles could be tracked in such areas as services and new business practices. It was suggested that NSF identify a few industries or sectors and fund specific studies to develop metrics on this broader notion of innovation.

10. University-Industry Knowledge Flows

Many observers believe that the relationship between universities and industry is an important source of the U.S. advantage in innovation. Data needs on this relationship include the following:

- fully developing metrics for the outcomes or outputs of university-based research joint ventures
- spillovers from universities to firms
- new organizational forms that have emerged from R&D collaboration

11. Data Needed to Support the R&D Satellite Account

NSF is funding the development of a BEA/NSF R&D Satellite Account consistent with the methodology of the U.S. National Income and Product Accounts. This project has identified key data needs, including capital expenditures and compensation cost details for scientists and engineers and support personnel.

Data Development Strategies

Much of the discussion at the workshop was focused on specific methods or approaches to developing data on innovation. The sense of the workshop was that the diverse strategies are not mutually exclusive and can be productively pursued in parallel or in combination. Furthermore, multiple data sources may be mined and integrated to yield additional indicators.

Several presenters stressed the need to support multiple measures of the same phenomenon whose errors are not correlated. The characteristics of a good proxy measure include high signal to noise ratio, unbiased errors, and a relationship between the proxy and the phenomenon that is linear (or understood) and stable over time and across different settings.

The approaches receiving the most attention were survey-based measures, data linking, nonsurvey-based measures (e.g., administrative data mining), and case studies and qualitative data.

Survey-Based Measures

As one speaker observed, the sample survey has been the method most commonly used to collect data for innovation-related indicators. The advantages of surveys are that they can be designed for consistent interpretation of questions, and thus permit comparisons among respondents. On the other hand, structured surveys reduce the flexibility of responses, potentially omitting important details and nuances. Among some survey populations, such as small firms, low response rates can limit the representativeness of response data.

Another speaker noted that the European Community Innovation Survey (CIS) has driven the development of international guidelines for collecting and interpreting innovation data, as defined in the OECD's Oslo Manual. The CIS has been conducted periodically since 1993, and similar innovation surveys are conducted by other countries, such as Australia, Canada, Japan, and the Russian Federation. The CIS is mandatory in some countries and voluntary in others, with the result that response rates differ markedly across countries. Little is known about who has used the data from the CIS surveys, what kinds of research and analysis they have done, or what impact they have had on policy.

Several participants observed that the United States does not have a comprehensive innovation survey similar to CIS. It was pointed out that the information from such a survey is fundamental to addressing questions of the health and vitality of the U.S. R&D system. Innovation is clearly a vital part of the picture. Without credible innovation indicators, it is difficult to demonstrate how investments in R&D lead to social and private benefits. There was strong support among some workshop participants for the recommendation in the 2005 CNSTAT report that NSF should resolve methodological issues related to collecting innovation-related data and initiate a regular and comprehensive program of measurement and research related to innovation.

However, it was also recognized that applying the CIS straightforwardly to the United States may not be appropriate, for such reasons as differences in statistical systems (e.g., centralized vs. decentralized structures) and statistical policy guidance (e.g., issues of respondent burden). NSF/SRS currently conducts a number of surveys that produce data related to innovation, including surveys of R&D expenditures and of human resources in science and technology. Although it does not conduct a separate, nationally representative survey of innovation, SRS has conducted some limited studies and surveys. As part of its industrial R&D recordkeeping study, SRS is asking about the ability of people in industry to answer questions on innovation beyond R&D inputs.

One strategy discussed was including innovation questions in the existing Survey of Industrial R&D (SIRD). An advantage to this strategy is that it would involve incremental modifications to a well-established survey. There was concern, however, that the people who respond to the R&D questions may not be able to respond to non-R&D innovation-related questions. There was some agreement that if the SIRD is broadened to include innovation, it must move beyond one simple survey instrument. Another concern was that the SIRD is a company-level survey, whereas a number of economic surveys are conducted at the establishment-level, which makes it difficult to link data.

Another strategy mentioned is to codevelop innovation-related questions in selected economic surveys, along with mining and integrating resulting data. Compared with a stand-alone innovation survey, this has the advantage of obtaining data automatically consistent with relevant supersets—consider, for example, total vs. innovation-related capital expenditures or revenues. Stand-alone innovation surveys may result in innovation data that are not methodologically consistent with related data.

NSF may also form public-private partnerships to proceed with smaller private experimental surveys in areas where consensus on which variables are important has yet to be established, while proceeding with a larger public survey that focuses on variables where consensus exists about their importance. For example, it was suggested that NSF might form partnerships with private-sector institutions that are collecting innovation-related data, such as the Association of University Technology Managers.

Data Linking

One of the key messages from the workshop was that there are a lot of fragmented data. One participant stated, "Patents, universities, people and human capital, internationalization—all are interlinked, but there are separate datasets and research communities for each."

Several presentations discussed the importance of identifying and linking existing data. In addition to needing new data with which to understand innovation, a number of participants recommended linking existing datasets, such as linking the National Bureau of Economic Research (NBER) U.S. patent data to the NSF/U.S. Bureau of the Census (Census) R&D survey. An ongoing NSF/Census/BEA project is linking the BEA data on U.S. direct investment abroad and foreign direct investment in the United States to the NSF/Census R&D data. One participant observed that if a survey is not linked to other surveys, one cannot follow through the R&D/innovation/diffusion/socio-economic benefits cycle. It was suggested that the Census Bureau, which conducts surveys for NSF and other sponsors, might do some arm-wrestling with sponsors and argue for more consistency among surveys in order to facilitate analysis and further data development.

The joint NSF/Census/BEA linking-feasibility study, completed in 2005, developed methodology necessary to link BEA data on MNCs with NSF/Census R&D data for all U.S. businesses. The link will facilitate integrated data covering domestic and international dimensions of R&D not available separately from the component surveys. The agencies linked U.S. MNCs parent data for 1999 and U.S. affiliate data for 1997 to all U.S. business data from the SIRD. The project also produced new preliminary data on basic research, applied research, and development for U.S. affiliates of foreign MNCs. This linking project also allowed sample and methodological improvements. Based on these positive results, the Census Bureau, NSF/SRS, and BEA are currently planning to conduct linking activities with more recent data.

It was suggested that Census, BLS, and NSF consider bringing together the BLS occupational data and the SIRD. In addition, data from SIRD, BLS data by standard metropolitan statistical area, and outside surveys of innovation could be linked. Although this might be technically feasible, whether it is appropriate to do so is a policy question. It might be appropriate to go to the Center for Economic Studies, a research unit of the Census Bureau established to encourage and support the analytic needs of researchers. It was also noted that BEA is planning to link MNC data to BLS occupational data because of policy concerns about the effects of offshoring on skills in U.S. firms.

Some speakers called for linking human resource data to productivity measures and linking innovation data to accounting structures.

Nonsurvey-Based Measures: Administrative Databases

As one speaker commented, the sample survey method is facing new challenges due to declining response rates. He suggested that utilization of administrative records may be the direction of the future. This approach relies on gathering information from collections of already existing data that were developed for some other purpose.

The speaker further suggested that integrating survey data with administrative data may solve some of the challenges facing innovation indicators. He gave an example of a study to determine the number of uninsured children at the county level. That study linked survey and demographic data sets to get information that was not contained in either set alone.

Data integration tools and algorithms are being improved, and they have significant potential to find new value in existing data. However, there are still gaps in the theory of how to integrate data. Among the principles suggested to guide data integration are the following:

- recognize that the estimand exists but is not always observed directly (latent variable principle)
- recognize that none of the bits of data contributing to the estimand are without error or uncertainty (uncertainty principle)
- model the relationship between estimand and data sources, with weight inversely proportional to the uncertainty of the data source (modeling principle)

Case Studies and Qualitative Measures

The strengths and weaknesses of case studies and qualitative measures were mentioned by several speakers. The case study method is especially useful in establishing causal paths, such as those between innovation and its socioeconomic impacts or between innovation drivers and innovation, and is often used in studies of innovation within the firm. One speaker noted that, at the micro level, smaller, more detailed studies tend to give more interesting and more informative results on how things work, but that it takes different kinds of methods to answer different kinds of questions. Moreover, as another speaker commented, the results of a case study cannot be generalized beyond the case itself and can be misleading. Thus, multiple case studies of a subject are often necessary but may result in a hodge-podge of different, incomparable kinds of data unless they are carefully designed and coordinated.

Speakers also commented on the need to combine quantitative and qualitative data in the study of innovation. As mentioned previously, one speaker observed that the burgeoning literature on university-industry knowledge flows uses both quantitative and qualitative data and methods, including case studies and event studies. Another speaker described the use of quantitative and qualitative data to identify and map regional nanotechnology assets and to assess a region's strengths and weaknesses in nanotechnology. This speaker observed that the choice of qualitative or quantitative data depends on the questions one is trying to answer. If a person can find data to answer the questions, he or she should use it, recognizing that it may take some transformation and it may not be perfect. If data are not available (for example, to learn what people's perception of nanotechnology is), other methods should be used. The speaker pointed out that non-quantitative knowledge—such as knowing where research is going on, who is doing it, and what its nature is—scan be extremely helpful in leveraging research and creating research synergies.

As one speaker noted "Trying to find a perfect innovation metric is like the search for the Holy Grail…what you should look for are multiple metrics with offsetting weaknesses."

Conclusion

Although workshop discussions did not produce an explicit assessment of which indicators are most urgent or immediately feasible, there was a sense that additional analysis of existing indicators and linking existing indicators were more immediately feasible than developing indicators that depend on new surveys or data sets. Further, diverse strategies are not mutually exclusive and can be pursued productively in parallel or in combination.

To some extent the optimal mix of data development strategies will be determined by policy and research needs, resource availability, comparative advantages across components of the U.S. statistical system, and the particular risks and benefits inherent in each approach. Participants urged NSF to work with researchers, other statistical agencies, and advisory bodies to further address relative strengths and weaknesses of the various alternatives.

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