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The Changing Research and Publication Environment in American Research Universities

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Executive Summary

Scientists and engineers ordinarily publish their research results in peer-reviewed journal articles. The number of these articles is an indicator of research output, although an admittedly imperfect one. In recent years, international use of this and related indicators has become widespread as countries have sought to assess their relative performance in science and engineering (S&E) research.

This report summarizes the views of experienced observers and practitioners in research universities about how the worlds of academic S&E research and publication changed between 1988 and 2003. It is part of a larger study by the National Science Foundation, Division of Science Resources Statistics (SRS), of changing patterns and trends in U.S. production of scientific articles since the late 1980s. The study was prompted by evidence that the growth in the number of U.S. articles, which had continued for more than two decades, began to slow in the 1990s even though research and development funds, research personnel, and similar research inputs continued to grow. At the same time, comparable evidence indicated that growth in article counts from leading research-producing countries in Europe and Asia continued unabated. The core of the larger study is a quantitative examination of patterns and trends in article production in the 15-year period between 1988 and 2003.

Data were gathered during visits to nine universities in the upper tier of the American academic research universe, where meetings were held with experienced researchers and research administrators across the spectrum of S&E disciplines. By visiting universities and talking with informants knowledgeable about academic research, SRS sought to better understand the changing circumstances that might affect the publication patterns observed in the quantitative data. Because the purpose in visiting universities was essentially exploratory, interviews and meetings ranged widely, probing changes and continuities in several domains, including how research is done, how the publication process works, and what activities universities foster and value. Perceived changes in research and publication outside U.S. universities, both internationally and in the U.S. nonacademic sector, were also explored.

Findings showed that peer-reviewed articles remain the major vehicle by which research findings are validated and scientists obtain credit for their contributions. Despite the rise of new forms of research output associated with advances in information technology, such as databases, software programs, and contributions to electronic archives, and new ways to disseminate findings electronically, there was little evidence to suggest that the validity of article and citation counts as output indicators was diminishing. According to those interviewed, data on article counts are unlikely to mask or distort real changes in scholarly output, except, possibly, in computer sciences. If U.S. researchers figure less prominently in the journal literature, the reason does not appear to be because they are reporting their findings in ways that bypass the journals.

Those interviewed consistently reported that the research done in other developed countries and in several emerging Asian economies is getting better and becoming more abundant. In their view, improved capacity overseas is more likely to account for the increased share of S&E papers from foreign institutions than changes in what Americans have been doing. In an expanding literature, they see a continuing, even growing, American presence, but more marked growth occurring in other countries.

Advances in communication have made the international scientific literature more accessible to researchers in other countries. In this regard, advances in electronic communication loom large. As potential contributors to the literature, researchers can take advantage of improved electronic communication to collaborate more easily with distant colleagues and submit papers online. As readers, they can receive papers from colleagues via e-mail, find information in electronic archives and databases, and access scientific communications that cannot be found in a local university library. In addition to electronic communication, increased capacity worldwide to communicate in a common scientific language, English, has also played a role.

As the largest and most influential producer of scientific articles in the world and a nation whose native language is also the dominant language of science, the United States was already at the center of the worldwide system of scientific communication before these advances occurred. Thus, journals were already highly accessible to U.S. researchers, both as contributors and as readers, at the outset of the period studied. Improvements in communication may have had a greater effect on the ability of researchers elsewhere in the world—especially those in nations or at institutions that were not prominent in research in the late 1980s—to keep up with their fields, produce research of a reasonable quality, and report their research in journals with a wider audience and a greater impact.

Institutional differences between the United States and other major research-producing countries may also be affecting article counts. The U.S. researchers interviewed for this study perceive their universities and funding agencies as less attuned to quantitative measures of output and impact than their institutional counterparts in other countries. As a result, U.S. researchers may be less concerned with producing scholarly output in ways that score well on these measures. Study informants stressed the role of expert judgment in maintaining the commitment to quality in the U.S. system and saw the system as being somewhat more oriented toward quality than in the past. They portrayed pressures toward scientific productivity as increasing, if anything, but as directed more toward enhanced quality than toward greater quantities of output. In contrast, many of the U.S. researchers interviewed saw other countries' efforts to improve research during the period under study as being increasingly driven by quantitative measures.

The study's findings provide little support for the idea that competing institutional demands are diverting faculty from research and publication. For the most part, informants said that neither teaching nor commercial activities were absorbing time that in the past would have been devoted to research and writing. Although some saw increased university concern about good teaching, and all agreed that institutional support for commercial activity was growing, faculty continue to believe that research is clearly the institutional concern that mattered most in shaping their behavior. It is possible, of course, that activities that compete with research for faculty time and attention, especially commercialization-related activities, have adverse effects on publication outputs that researchers themselves do not fully appreciate.

One of the most striking recent changes in how research is done has been the movement toward more collaborative work, especially interdisciplinary and interinstitutional collaboration. Study data suggest that this trend can have either of two opposite effects on publication output. Insofar as it involves "complementary" collaborations that increase research output via a more rational division of labor, it should generate increased numbers of publications. However, insofar as this trend involves "integrative" collaborations that require extensive communication to synthesize different perspectives on a problem into a coherent piece of research, more people, money, and time may be required to produce a publishable article. It is possible that growth in publication output has slowed as a result of a movement toward integrative collaborations. Some informants suggested that successful integrative collaborations have had disproportionate impact on their fields and that the United States has been in the forefront of movement toward this type of collaboration. If U.S. researchers, compared to researchers in other countries, had been more rapidly increasing their investment of time and resources in this type of collaboration, this might help explain the change in article counts.

The increasing time and effort that U.S. researchers say they devote to securing funding may also adversely affect U.S. article counts. Some researchers said that in the United States, competitive mechanisms intended to spur productivity sometimes and increasingly had the opposite effect, even as other countries profited from introducing more such mechanisms. Similarly, although some informants indicated that regulatory and governance burdens are increasing at U.S. universities, there was little to indicate whether the situation in other countries is different in this regard.

Purpose and Scope

This report summarizes the views of experienced observers and practitioners in research universities about how the worlds of academic science and engineering (S&E) research and publication changed during the 15-year period between 1988 and 2003. It is part of a larger study by the National Science Foundation (NSF), Division of Science Resources Statistics (SRS) on changing patterns and trends in U.S. production of scientific articles since the late 1980s. Scientists and engineers ordinarily publish their research results in peer-reviewed journal articles, and the number of these articles is an indicator of research output, although an admittedly imperfect one. In recent years, international use of this and related indicators has become widespread as countries have sought to assess their relative performance in S&E research.

SRS's study was prompted by evidence that the growth in the number of U.S. articles in the Institute for Scientific Information (ISI) standard comprehensive database of scientific articles, which had continued for more than two decades, began to slow in the 1990s. Since then, the volume of U.S. articles has remained virtually unchanged. This flattening of U.S. output occurred even though research and development funds, research personnel, and similar research inputs continued to grow. At the same time, the ISI database indicated that growth in article counts from leading research-producing countries in Europe and Asia continued unabated. As a result, the U.S. share of worldwide S&E publications has been declining. Whether and how the sheer number of U.S. publications (including publications not included in the ISI database) or the number of publications per researcher changed during this period is more difficult to establish.

SRS plans to publish results from this study in a series of reports focused on different aspects of the issue. The core of the study is a quantitative examination of patterns and trends in article production in the 15 years from 1988 to 2003. SRS report *Changing U.S. Output of Scientific Articles: 1988–2003* (NSF 07-xx) describes these patterns and trends, and a forthcoming report will use quantitative analyses to explore possible explanations for these patterns and trends.

The present report, however, is entirely qualitative. It describes how knowledgeable and experienced participants in academic research and publication perceive the changing contexts in which their work occurs. The purpose is essentially exploratory—to report observations that may point to further lines of inquiry or suggest possible explanations of observed patterns and trends in scientific publication that may be examined in further research. Exploratory work such as this helps put quantitative findings into context, as well as yielding insights into possible ways to analyze existing quantitative data and possible new data that could be collected.

For the most part, this report presents a descriptive summary of what the researchers said and refrains from discussing the implications of the findings. The report's conclusion, though, notes some possible implications of these findings for efforts to make sense of the quantitative publication trend that prompted the study.

Data for this report were gathered during visits to nine research universities, where the study team met with researchers and research administrators across the spectrum of S&E disciplines. Members of the study team visited universities in four states: California, Illinois, Massachusetts, and North Carolina. The team tried to select a mix of universities—large and small, public and private, urban and rural, with and without medical schools, and with varied trends in their output of journal articles. Each of the universities visited can be considered part of the upper tier of the American academic research universe. As a group, they are not a representative sample of that tier, but their range of characteristics is in keeping with the range found among America's leading research universities. However, one reviewer who read a draft of this report opined that, judging by his visits to several of the universities studied, this group of universities appeared to be "more favorably disposed to expert judgment, interdisciplinarity, and qualitative measures than other large universities, especially public institutions." Appendix A lists the universities visited.

In almost all cases, the study team asked to talk with people who had been involved in research for 15 years or more and would therefore have a sense of how publication practices had been changing; the team also met with less experienced researchers to find out whether their perceptions of the current research environment were substantially different from those of their more experienced counterparts. The team sought people with different roles in the research enterprise—faculty members who ran individual laboratories, department chairs, heads of interdisciplinary centers, and administrators with a large measure of overall responsibility for administering either the research or education activities on campus. In most cases, interviews and meetings lasted 1.5 to 2 hours. Because the university visits averaged about 2 days, the team met with between 10 and 30 people per campus, depending on the balance between individual and group sessions and the size of the groups. Each visit included one or two interviews with high-level administrators who provided an overall perspective on changes in their university's research, education, and publication environment. Appendix B provides more detailed information about how the data were collected.

By visiting universities and talking with informants knowledgeable about academic research, SRS sought to better understand the changing circumstances that might affect the publication patterns observed in the quantitative data. In keeping with the study's exploratory purpose, interviews and meetings ranged widely, probing changes and continuities in several domains, including how research is done, how the publication process works, and what activities universities foster and value. Perceived changes in research and publication outside U.S. universities, both internationally and in the U.S. nonacademic sector, were also explored.

One issue central to the study is the changing role of peer-reviewed articles as a vehicle for disseminating scientific output. Analyses of article production do not capture other kinds of output that have long been significant in some fields—notably, books in many social sciences and psychology and products and processes in engineering. More importantly, article and citation counts do not register new forms of output associated with advances in information technology, such as databases, software programs, and contributions to electronic archives. In visiting the universities, SRS sought insight into whether the validity of article and citation counts as output indicators was changing, how article and citation data should be interpreted, and what other kinds of output might be used as indicators in the future.

Although scientists and engineers in various institutional sectors—universities, industry, government, and nonprofit organizations—produce research articles, this report focuses on the academic sector. This sector is by far the largest source of articles and tends to produce the articles that are most influential and that appear in the most influential journals. Moreover, within the academic sector, the study team chose to visit institutions at or near the forefront of the academic research system, which define research as a central component of their mission and produce large numbers of articles. The state of the research enterprise in institutions such as these is especially relevant to U.S. leadership in S&E worldwide, and developments in such

Because the goal of SRS's larger study is to understand trends in research output, the major focus of this report is change. However, the report inevitably gives some attention to enduring features of the academic landscape that help set the context for the changes observed.

Findings

Researchers produce publications by doing research and then disseminating the results. Changes in the quantity of articles can occur because of changes in resources—funds, personnel, facilities, and equipment—being devoted to research. Quantitative data are well suited to describing these changes. Other phases of the SRS study explore the relationship between changes in resources and publication output.

Changes in article counts can also occur when researchers adopt either different ways of doing research or different systems of dissemination. Qualitative data from interviews with knowledgeable informants provide valuable indications of these kinds of changes. This report presents what the study's university informants said about what is and is not changing in each of these two areas. The section on the research process deals with the changing characteristics of the people, sources of information, equipment, and facilities that are involved in generating research findings. The section on how research is disseminated describes consequential developments in the way researchers report results and get credit in their professions for having generated findings.

Changes in research and dissemination processes, in turn, are affected by the larger institutional and global environments in which scientific inquiry occurs. Institutions such as universities, funding agencies, and the commercial market affect how academic scientists and engineers do their work. The section on the institutional environment deals with changes in the opportunities and constraints these institutions create for university-based researchers. The focus is on actions that these institutions induce in research and publication. The section on the global environment addresses how research in other countries and the relationship between U.S. and world science are changing.

The Research Process

Collaboration

University researchers and administrators say that research has become more collaborative in practically all respects. Scientific articles more frequently involve authors from more laboratories, more institutions, and institutions in more countries. Collaborators are more often trained in different disciplines. Some of the study's informants also noted that collaborations with researchers in other institutional sectors, especially industry, were becoming more common.

When researchers refer to collaboration, they describe a range of relationships falling between two polar types. At one pole are collaborations among people who have complementary data, access to complementary equipment, or expertise in complementary techniques. In these collaborations, coauthors are responsible for different parts of an article, and few issues arise that affect the article as a whole or require substantial interaction among coauthors. At the other pole are collaborations among researchers with fundamentally different perspectives who need a common understanding of the issues that their work will address and cannot divide their joint work into discrete pieces that individual scientists can handle autonomously. These collaborations involve extensive discussion among cooperating researchers and can transform the way individual researchers approach the problems they study. For brevity, this report refers to these two types of collaboration as "complementary" and "integrative," respectively.

Since researchers themselves do not conventionally divide collaborations into these categories, they did not always clearly indicate which type of collaboration accounted for the overall increase in collaboration. The study team received strong indications, however, that both played a part. Numerous factors facilitate the increase in collaboration:

- Electronic communication makes collaboration easier in several ways. Collaborators in different places can quickly exchange written information without the delays associated with physical transmission of paper. In many countries, Internet communication also is more reliable than mail. Electronic databases enable researchers to search for relevant literature and identify suitable collaborators more easily than in the past. In certain areas of science, the availability of electronic media that transmit high-quality visual displays has also been important for collaborative work.
- Improvements in travel allow many researchers to attend more conferences, including international meetings, enabling them to meet potential collaborators and initiate working relationships. The researchers then sustain these relationships through electronic communication.
- Many researchers believe that the most promising research problems now require multiple techniques and perspectives that are beyond the capacity of individual laboratories. In their view, the development of their sciences has driven researchers toward collaborative work. One biologist provided an example of how the development of her science had led to more collaboration: with the availability of genomic data, researchers had identified certain genomic phenomena that crosscut species, prompting collaboration among researchers specializing in different species to explore these phenomena more thoroughly.
- Many funding agencies, especially in the federal government, share the view that collaborative and multidisciplinary teams are the best way to address some of the most significant scientific issues. They therefore encourage collaborative research as a matter of policy, and the research community responds to the funding priorities of the granting agencies.
- Some of the universities visited explicitly encouraged collaborative research on their campuses, particularly among faculty members in different disciplines.
- Especially in the biological sciences, some researchers claimed that top journals required increasing numbers of tests and techniques to document arguments. Individual principal investigators (PIs), unable to develop adequate in-depth knowledge of all of these techniques in their own laboratories, seek collaborators with complementary skills. A biochemist, for example, reported that almost all of her research now involves collaborations with a microscopist and a pathologist.

The two polar types of collaboration can have different implications for output. Complementary collaborations take advantage of the efficiencies ordinarily associated with the division of labor when applied to well-understood tasks. Integrative collaborations involve the communications overhead associated with overcoming differences and developing teams. In describing integrative collaborations, some researchers praised the intellectual excitement of bringing different perspectives to bear on a common problem and pointed to innovations that resulted. But researchers also said that the effort to develop shared perspectives in a diverse group means that the distinctive products of this type of collaboration take more time to produce.

Interdisciplinarity

Researchers report that they do more interdisciplinary work. Some of this involves collaboration with what are conventionally thought of as neighboring disciplines. Thus one astronomer stated that the different subdisciplines within astronomy are more likely to collaborate than in the past. But some interdisciplinary work connects researchers in historically disparate fields. The study team was often told that biology in particular had become markedly and radically more interdisciplinary, developing increasingly strong links to physics, mathematics, statistics, engineering, and various kinds of environmental science. Stronger ties among the disciplines within biology, manifested in studies examining relationships among biological phenomena at levels ranging from molecular to behavioral, were also mentioned frequently. Computational sciences, including mathematics and statistics as well as computer sciences, were another area where researchers reported substantial growth in interdisciplinary work. Aided by increasingly sophisticated computers, researchers with mathematical training were finding new opportunities to collaborate with those involved in various fields of empirical research.

Researchers often, but not always, associated interdisciplinarity with larger research groups and with centers constituted around interdisciplinary problems. But university departments themselves appear to be becoming more interdisciplinary. In a meeting of department chairs, for example, the study team was struck by how many chairs described their departments as spanning different disciplines and including faculty members with affiliations to research units in many parts of the university. Although some of these departments were explicitly constituted around an interdisciplinary vision, many represented "traditional" or "core" disciplines that had expanded their boundaries to include faculty members with backgrounds and affiliations that would not hitherto have been represented.

Access to the Literature

Although researchers were making continuing, and perhaps increasing, use of library services, they said that they rarely visited libraries any longer. Instead, they were using the electronic search capabilities and database subscriptions that their university libraries provide to find relevant literature. Researchers consequently were doing more targeted searching using key words, which has enabled them to access a broader range of directly relevant literature more efficiently. At the same time, they reported doing less undirected browsing, especially outside the journals with the highest visibility. Some lamented that their more targeted reading had led them to make fewer serendipitous discoveries in the journals. They also noted that older literature, when it is not covered in the electronic databases, effectively becomes inaccessible. Many researchers noted that the Internet has made the literature more accessible to them and increased their productivity as a result. But the study team was also told that time to read and think was becoming scarce and that electronic access neither reduced the importance of these activities nor meaningfully increased the efficiency with which they could be done.

Personnel

For the most part, experienced researchers reported little or no change in the availability of capable subordinate personnel—graduate students, postdocs, and technicians. They expressed various, mostly tentative, generalizations about how younger researchers differed from the young researchers of their generation—more careerist, more interested in translating research into practical applications, less concerned with the big scientific questions, more interested in commercial activities, less characterized (especially if U.S. born) by a single-minded devotion to science. However, they almost never associated these differences with any substantial effect on output volume.

Equipment/Technology

Equipment needs have increased in many fields. Researchers frequently complained that their own laboratories or universities lacked equipment that was necessary for their research, though they generally said they were able to get access to such equipment in shared facilities, either at their own universities or elsewhere. Start-up packages to enable new faculty members to equip a laboratory have become substantially more expensive in many fields.

How Research is Disseminated

Journal publication has traditionally been the conventional way to disseminate research results and other significant scientific contributions. Although other outlets for dissemination, such as conference presentations, books and book chapters, and government reports, have also existed, scientists generally have looked to journal articles for reports of new findings by their colleagues.

Journal publication has also been the most important way for scientists to secure credit for their research contributions. Because journals, unlike some other publication outlets, publish articles only after expert reviewers conclude that the work is worthy of being published, publication signifies that an article has sufficient merit to survive the scrutiny of peer review.

Researchers interviewed for this study described numerous changes in the ways research findings are disseminated, many involving new ways in which journals do business in an era of electronic communication. Some of these changes challenge the centrality of journals to the dissemination of scientific findings. However, informants described almost no changes in how scientists accrue credit for their work. For assigning credit, unlike for dissemination, the centrality of journals is unchallenged and undiminished. Only the field of computer sciences, discussed separately below, is an exception to this generalization.

The Peer-Reviewed Article as Indicator

The researchers interviewed strongly affirmed the continuing centrality of peer review to the evaluation of scientific work. None of them indicated that peer review had in recent years become less important to assigning scientists credit for their research. The study informants said that journals added value to research reports in large part by administering a peer review process. Accordingly, they viewed journal quality as mostly a function of the quality and rigor of the peer review process. Similarly, in discussing tenure and promotion, they stated that peer-reviewed research that appears in journals is the cornerstone of a candidate's dossier and that other kinds of research output are at most supplementary. In the rare disciplines that gave substantial weight to research reports disseminated in media other than journals, validation through peer review was an essential element of assigning credit.

More typically, according to study informants, because peer-reviewed journals were the route to scientific credit, scientists remained as committed as ever to reporting their significant findings in journals and nearly all significant contributions appeared in journals. This was true even in fields where additional modes of dissemination had become increasingly important and where versions of the research were initially disseminated through other modes. Thus, study informants agreed that article counts are at least as good an indicator of scientific productivity now as they were in the past and that any limitations of article counts in this regard have not become more significant in recent years.

Scientists continue to report research in books, book chapters, conference presentations, and annual review articles and in recent years have begun contributing to Web archives as well. Research reports in traditional paper media other than journals have generally not increased in importance, and there were some indications that they may have declined. Publications in books have suffered increasingly from lack of timeliness in keeping pace with the rapidly moving scientific frontier, especially in the biosciences. Opinions about review compendia were mixed: Some perceived them as more important in helping readers gain an overall perspective on a burgeoning literature, but others believed they suffered from the same timeliness problems as books and book chapters. Conference proceedings, except in the computer sciences (discussed below), were not seen as competing with journals for high quality material. Similarly, non-peer-reviewed papers posted on the Web, though significant in some fields as a means of disseminating new findings, were not considered a substitute for journal publications.

Advances in Information Technology

Although technology has not substantially altered the role of peer reviewed journals in the allocation of credit for scientific contributions, it has been changing the ways that researchers make their findings known. In interviews, researchers noted the following changes in journal operations:

- Journals can publish electronically on the Internet. Internet publication can be an adjunct to paper publication or can be the primary or exclusive form in which a journal is published. When a journal publishes both print and electronic versions, the electronic version can faithfully replicate the print journal, take extensive advantage of unique properties of electronic presentation (e.g., streaming video, links to related data), or do something in between.
- Prior to formal publication and acceptance, manuscripts can be disseminated through preprint archives on the Internet. Researchers in physics, mathematics, astronomy, computer sciences, and related disciplines reported that for access to the latest research findings, they relied on ArXiv, an unrefereed online compendium of manuscripts in their fields.
- Although a journal's prestige is largely a product of the perceived quality and selectivity of its peer review process, accessibility also plays a role. Several researchers said they preferred to submit to journals that published readily accessible electronic versions, since this increased the chance that others would see their work. They viewed electronic versions that were available only long after paper publication or to subscribers who pay high fees as less desirable. University libraries are gatekeepers for electronic access as well as for access to print journals.
- Conducted electronically, a journal's peer review and manuscript handling processes can move more rapidly, enabling the journal to make quicker decisions about whether to accept the manuscripts that scientists submit. Because electronic processing does not materially affect how quickly reviewers can read and evaluate submissions, however, its overall effect on processing time was generally limited.
- Nonetheless, competitive pressures and technological opportunities have facilitated somewhat faster manuscript processing. Authors prefer journals that make faster decisions, and electronic administration during manuscript review gives journals greater control over their processing speeds.

- Insofar as journal review becomes faster, researchers can more easily afford to have a manuscript rejected, because rejection does not unduly delay publication. They can initially submit to top-quality journals where success is unlikely and later submit to less selective and prestigious outlets.
- Available software enables scientists to do professional drafting for complex graphics at their desktops.
- Many researchers make their work available on their Web sites, which can be a significant communication vehicle. Web sites are unreviewed, do not establish priority, and do not generate credit. One researcher said they have "the formality of a coffee shop conversation."

Changes in the Publishing Business

Spurred in large measure by new cost-shifting and access-altering features of electronic dissemination, the journal publishing business has been changing. Many researchers noted that journals had become far more expensive, causing libraries to limit or reduce the number of journals to which they subscribe and publishers to adopt various strategies to maintain their library subscription income. The study team heard numerous complaints about commercial publishers and spoke with some proponents of open-access publishing, in which the author (or the funding agency that sponsored the author's research) pays the cost of publication. Study informants gave considerable evidence that the business model for scientific publication is in flux, but almost no evidence that recent developments had generally changed whether or when researchers chose to publish their work in journals. Although the ongoing changes in the publishing business have potentially far-reaching effects on scientific communication, none of the informants said these changes had in fact had a big impact on article and citation counts, and none offered ideas about why these changes would have produced any impact at all thus far.

Changes in Published Papers

Many study informants said the volume of published scientific journal articles had increased, with the numbers of journals, issues, and articles per journal issue all growing larger. As a result, they reported that, if they simply wished to report a finding somewhere, it was easier to get an article published than it had been in the past. Many said that the minimum required scientific contribution for articles in their fields (the "least publishable unit") remained essentially unchanged, although certain information, such as gene sequences, because technological and scientific advances had made it much easier to obtain, was no longer sufficient to render an article publishable.

At the same time, researchers reported that standards at the better journals—journals with the highest impact in a particular specialty and high-impact interdisciplinary journals—had risen. Many researchers said that publishing in these journals had become harder, and though a substantial number thought there had been no change, none said it had become easier. In this more competitive environment, several scientists claimed that these journals demanded revisions more often than in the past.

Many informants said the prestige premium attached to publishing in top journals had increased. In many fields, this was especially true for the two leading English-language interdisciplinary journals, *Science* and *Nature*. Researchers offered various explanations for the increasing prestige of these journals. These explanations included the "marquee" quality of journals that reached a wide audience in an era of increasing specialization and the growing importance of placing one's work in a context that highlighted its interdisciplinary implications and brought it to the attention of a diverse audience. However, informants said that successful careers could be built on a record of consistent publication in high-quality specialized journals.

Researchers said that at the top journals higher standards generally meant employing a greater range of experimental techniques and greater sophistication in the statistical analyses used to document a particular result. A few lamented that inferences from related theory and discussion of unresolved issues had become harder to include in articles, since these could be taken as indications that further experimental evidence was needed to provide definitive empirical tests of open questions; one scientist said that in her field more theory-laden discourse was moving out of the research journals and into review articles.

In many fields, a trend toward "letters" journals, which feature brief reports of significant findings, has partially or completely countered the trend toward longer, more comprehensive articles based on more experimental data. Like articles in *Science* or *Nature,* a report in a letters journal can serve as the "headline" announcing a research result and establish priority. Researchers said they would often follow these short articles with a more complete report in a specialty journal that provided the space for it.

Citations

The researchers the study team spoke with said that, although norms governing citation practices had not materially changed in recent years, actual practice had evolved somewhat in light of some new realities. They noted increasing tendencies to cite more accessible review articles rather than search for the original research on which the reviews were based, pointing out that this introduced additional inaccuracy in assessments that relied on citation analysis to measure the influence of original research. Another significant change was increased reliance on electronic searches for sources, which made findings that predated the major electronic databases effectively inaccessible and, therefore, rarely cited. In addition, some journals impose limits on the space they devote to citations, leading researchers to omit citations they consider less important.

Disciplinary Variation

Researchers in different disciplines saw the pace of change in research and publication processes differently. Chemists and social scientists mostly painted a picture of relatively gradual changes, whereas biologists and mathematicians were more likely to describe much more rapid developments. Yet, in most respects, researchers characterized the overall direction of scientific change in fairly similar terms.

Nonetheless, there are some fields in which special circumstances have caused research and publication to move in unique directions. Field-specific patterns and trends stood out in clinical medicine and computer sciences.

Clinical Medicine. Almost alone among those interviewed for the study, several researchers in clinical medicine said that they would not be surprised to discover that U.S. publication output was no longer growing and that U.S. science was losing ground to work done in Europe and Japan. Clinical researchers cited numerous problems that beset their field and that had not been solved by the infusion of federal research funds toward the end of the 1990s. There was broad agreement about the following developments:

- In the mid-1990s, Medicare and other insurers tightened their practices for reimbursing medical research organizations for patient care. Reimbursements per patient fell, documentation requirements increased, and overhead funds from patient care activities that could be used to support research expenses disappeared.
- Clinical departments responded to these developments in insurance practice in part by increasing the number of hours faculty members with primarily clinical responsibilities devoted to patient care. Fewer of these faculty continued to play a significant role in research.
- The best clinical research was becoming much more sophisticated and required extensive and varied skills. These ranged from familiarity with modern molecular biology and genomics to skill in designing "translational" research that investigates how laboratory findings can be applied to patient care. Research on health care delivery likewise was drawing on an increasing range of disparate disciplines. Several researchers expressed enthusiasm about new directions in research while at the same time stating that they found it more difficult to pursue their research interests in a changing institutional environment.
- Clinical faculty were finding it more difficult to remain current in both clinical and research skills, and almost all were choosing to specialize in one or the other. In an earlier generation, faculty were able to sustain significant involvement in both arenas.
- Experienced physicians saw careers in clinical research as increasingly insecure, and such careers were correspondingly unattractive for new physicians, who have other options. Clinical faculty are in "soft money" positions, which require a steady supply of external research support, and success rates for grant applications in their field are low.
- Regulatory requirements relating to clinical research became more complex and costly. Meeting these requirements led researchers to take time away from research to perform what many consider to be onerous administrative tasks.
- Because the U.S. medical system is more fragmented than the systems in other developed countries, patients are more difficult to recruit and clinical trials more difficult to administer. This, combined with the regulatory and recordkeeping burdens that U.S. clinical trials involve, caused more clinical research to move to other countries. There are also countervailing pressures to do drug testing in the United States, however. Thus one researcher said that performing clinical trials in the United States facilitated getting Federal Drug Administration approval for marketing new drugs to the large U.S. market.
- Pharmaceutical companies are spending more on drug development and testing, and some scientists, lured by high salaries and the promise of a less stressful work environment, have left academic medicine and moved to industry.

According to study informants, the net effects of this set of changes were that research funds did not go as far and personnel were less able to focus on research and publication. They said that, on the whole, the circumstances for doing clinical research in other developed countries were more favorable and that the comparative advantages these countries enjoyed appeared to have been growing.

Computer Sciences. In computer sciences, proceedings of peer-reviewed invitational conferences and workshops are an important and valued publication outlet.

Acceptance rates can be low for prestigious conference proceedings. Computer scientists reported that journals have proven to be too slow to keep pace with a rapidly changing discipline. Because of the premium on speed, revision and resubmission is rare. Funding agencies and central university administrations have learned to take into account the special features of publication in computer sciences in evaluating faculty research records.

The Institutional Environment

In deciding how to publish their work, researchers are attuned to the signals they receive from the institutions in the research community. These institutions include the following:

- The universities in which research is conducted and career-shaping decisions about appointments, promotions, and tenure are made.
- The disciplines and interdisciplinary research communities that confer status on prominent researchers.
- The commercial enterprises that translate research into saleable products and offer the prospects of significant financial rewards and the adventure of entrepreneurial endeavor.
- The government agencies that fund research and regulate how it is performed.

This section reports on the changes and continuities in the institutions that define the standards by which academic research is judged and that reward researchers for their accomplishments.

University Priorities and Measures

Universities generally do not use quantitative metrics to measure research output, especially when assessments are consequential. Formal measurement processes have made some inroads in shaping allocations of faculty salary increases, for example, but tenure and promotion decisions, which involve major, long-term commitments, are seen as irreducibly qualitative, especially at the most prestigious universities. The biggest exception to this generalization was the clinical track of one of the medical schools visited, and even in that case, the basic sciences track avoided formal metrics in assessing publication output.

In tenure and promotion decisions, universities rely heavily on letters from distinguished researchers assessing the distinctive contributions candidates have made to scholarship in their fields. According to study informants, these letters were no less important than they had been in the past, and some informants said they were more important. Others stressed the importance of a cogent, detailed letter from the department chair or tenure and promotion committee laying out for university administrators outside the candidate's department the reasons why the candidate's work was important. Although letters could invoke quantitative indicators to buttress a case for tenure or promotion, informants viewed the essence of the case as an argument about the quality and, especially, the impact of a researcher's work. One researcher stated that a letter that rested its case on quantitative indicators would be dismissed out of hand.

Informal quantitative standards did play a role in tenure and promotion decisions by setting approximate productivity thresholds below which a university would presume that a candidate was not competitive. Even these thresholds, however, were discussed as guidelines, and faculty members readily supplied anecdotes about individuals who received tenure or promotion because they were able to demonstrate major impact despite a relative paucity of publications.

The increasing importance of collaborative research has tended to underscore the importance of qualitative expert assessment. Faculty and administrators involved in making tenure and promotion decisions said that inferences from placements in authorship lists were no substitute for rich descriptions of the roles of individual scientists in collaborative efforts. Most study informants saw universities as increasingly confronting the problem of identifying the distinctive contributions of junior researchers to collaborative enterprises, but most saw this as a manageable issue that was unlikely to lead to substantial changes in how faculty were evaluated. Some noted that the premium on demonstrating a distinctive individual contribution to science made some junior researchers reluctant to engage in predominantly collaborative work, even when they believed they could be most productive in this way.

Because the significance of journal publications varies along a variety of dimensions—article quality, journal quality, role of any particular scientist in the group of authors, placement in the authorship list—article counts would require numerous adjustments before they could be used as a valid measure of research contributions. No one interviewed seriously proposed article counts as a viable way of evaluating faculty.

Although impact was portrayed as central, impact factors—quantitative measures of citation frequency using ISI data—elicited diverse reactions. One department chair said he initially had been enthusiastic about a quantitative measure of impact until he looked at the citation measures for his own work and concluded that some of his lesser work was among his most highly cited papers. Other researchers, however, expected that impact factors would become more important because computerized databases made them readily accessible without significant cost. Several informants also noted that impact factors and other quantitative indices became somewhat more salient as a tenure or promotion portfolio ascended to higher levels in the university and was reviewed by people more distant from the candidate's field.

Overwhelmingly, faculty and administrators believed that expert judgment, despite some risk of arbitrariness and selection bias, is superior to existing metrics. Some of the universities visited had instituted controls on the selection of experts to improve the objectivity of the evaluations produced by the process. Despite the effort and expense involved in securing expert evaluations, a university that had abandoned outside expert evaluation for making promotions within the ranks of full professors reinstituted the practice because it concluded that such evaluations were important for making creditable evaluations.

For universities, the most salient quantitative measure of research activity is not publication counts or impact factors, but external research funding, especially when competitively obtained. Study informants reported that funding could be useful as a threshold measure, given that external support is necessary for sustaining an adequate level of research activity. One administrator said that funding levels, by providing an indication of competence in the "business side" of running a laboratory, complemented publication measures, which indicated proficiency in the "research side."

Researchers familiar with faculty evaluation in leading European and Asian countries reported that universities in those countries relied much more heavily on quantitative measures. One researcher recalled his shock at learning that universities in France and Israel determined whom to hire by using publication counts. Another faculty member marveled at how concerned postdocs from other countries were with the impact factors of the journals to which they considered submitting manuscripts. She attributed improved performance on quantitative indicators in these countries to the centrality of these indicators to performance assessment and faculty members' career prospects. Like practically all of the scientists who commented on this issue, she compared these quantitatively oriented systems unfavorably with the qualitative expert judgment evaluations prevalent in American universities. Perhaps the most supportive comment on strict adherence to quantitative standards for measuring publication output was the suggestion that rapidly improving university systems might have few alternatives to such standards. Thus one department chair argued that because senior faculty in these systems often lack both the ability to make reliable expert judgments on the quality and impact of the work of their junior colleagues and the wherewithal to elicit such judgments from international experts, quantitative standards might actually produce better results than expert judgment. He added, however, that American research universities did not find themselves in these circumstances.

At many universities, some researchers said their institutions were paying more attention to teaching, though not everyone agreed that this was a real change. There was overwhelming agreement, however, that incremental attention to teaching was not expected to come at the expense of research and that research was the decisive factor in faculty evaluations. Similarly, faculty members said that they met increased demands in other areas, such as proposal writing and administration, simply by working longer hours, since they could not afford to reduce the time they spent on research.

Visibility

Because expert assessment of researchers' impact in their fields is so important to career success, faculty need to make themselves and their work visible to influential people who work on related intellectual problems. Study informants pointed to some modest incremental changes in the paths to visibility, but the study team heard nothing to suggest that published research played a substantially diminished role. At elite universities, informants mentioned the Nobel Prize and other competitive public prizes, prestigious awards from professional associations, memberships in one of the U.S. National Academies (which recognize distinguished researchers in engineering, medicine, and the sciences), and major invited addresses at important national and international meetings as signs that a scientist's body of work had achieved truly significant recognition. In discussing how scientists achieved this level of recognition, senior researchers stressed the importance of what one researcher labeled "jewels"—articles that made decisive or path-breaking advances.

Many researchers also reported that the most widely recognized interdisciplinary journals, especially *Science* and *Nature*, had become more important vehicles for achieving visibility, particularly in fields where these journals publish substantial numbers of articles. Although the study team heard some skepticism about the enduring importance of some of the work that appeared in these journals and frequent reminders that space limitations in these journals precluded publication of important details of evidence or argument, scientists expressed little doubt that papers in these journals were widely noticed. Appearances at well-chosen conferences were viewed as another effective vehicle for achieving visibility, and some scientists, though by no means all, believed that conference attendance had become somewhat more important in recent years. They saw this as a response to an environment in which there were more journals being published, but fewer journals that most people in one's field could be counted on to read.

Quality and Quantity

When asked whether their universities had altered the relative value attached to quality and quantity in researchers' publication output, study informants generally said that U.S. universities had moved modestly in the direction of emphasizing quality. They characterized the change as modest in part because they perceived top universities as having consistently stressed quality throughout the period under study and in part because they perceived institutions less distinguished than their own as being less discriminating about quality and more interested in sheer numbers of publications. Several researchers noted recent changes at funding agencies that indicated a shift in emphasis toward quality. They said that NSF and Howard Hughes, by requiring grant proposals to cite a limited number of the PIs' "most significant" publications rather than include a complete list of their published work, had placed an increased premium on quality.

Researchers vary in how they balance quality and quantity in publications, and the institutional environment does not strongly enforce a particular balance. The study team heard no clear indications of a consensus that the balance was shifting toward one pole or the other, let alone that it was shifting decisively. At each university visited, researchers reported that some of their colleagues favored a smaller number of relatively comprehensive publications, whereas others tended to produce more frequent reports of more limited sets of findings. They portrayed the institutional system as sufficiently flexible to accommodate individual preferences in reporting styles within relatively wide limits.

Commercialization

At all of the universities visited, researchers reported that commercial application of research results was a more real possibility than in earlier times, that more faculty members and students were engaged in commercial activity, and that, for the most part, universities were seeking to make themselves more hospitable to faculty members who try to pursue commercial possibilities emanating from their work. The growing prominence of commercial possibilities in biomedical research was especially pronounced. In other respects, fields that traditionally have been removed from significant commercial activity, such as basic social sciences and astronomy, remained so, while fields that more readily translated into technological applications, such as engineering and chemistry, continued to stress the commercial implications of academic research.

Very few study informants, however, thought that commercially oriented activity had significantly reduced the amount of publication-oriented research. Most reported that faculty colleagues who had gotten involved with start-up companies had continued to publish. They noted that these researchers tended to be very active and innovative, so that their commercial activity was more an addition to their academic research than a replacement for it. In addition, commercial involvements sometimes enriched the published work of faculty researchers, involving them in new areas of research. Many people observed that awareness of the commercial potential of research sometimes prompted brief delays in publication, but they generally doubted that these delays caused an overall reduction in publication.

Faculty commercial activity has hidden costs, however. One is the overall administrative infrastructure necessary to support it. Thus one department chair said that although faculty affiliated with companies in his department continued to perform and publish research, management activity traceable to their dual affiliations took a disproportionate amount of his time as department chair. An important element of this management activity is making legal arrangements that are necessary for faculty commercial activity. Participants in a group meeting of biomedical department chairs said that because the commercial and proprietary implications of sharing research materials loomed larger than in the past, researchers were required to spend much more time arranging materials transfer agreements; other researchers interviewed echoed this theme.

Some informants spoke about adverse affects on academic research brought about by the decline of large industrial research organizations, such as Bell Laboratories, that engaged in long-term research not specifically tied to product development. They claimed that such organizations had formerly been sources of valuable information for academic researchers about the kinds of findings that might have promising industrial applications. In addition, they said that scientists and engineers in these organizations had served as liaisons between academia and industry, explaining to corporate decisionmakers why it is important to support university-based research that does not promise immediate benefits.

At the same time, some informants pointed to a tendency for academic researchers to engage in more studies oriented toward practical problems and real-world settings. They said that scientists had developed a greater appreciation for the value of studying phenomena in natural settings, similar to those in which proposed interventions would occur, rather than in more controlled contexts. Such research was often characterized as also more interdisciplinary and applied, though not necessarily commercial in orientation. Other researchers lamented what they saw as an increasingly engineering-oriented ethos in what traditionally had been basic science disciplines.

Securing Funding

Those interviewed repeatedly told the study team that researchers were putting much more effort into securing funding than they had in the past. Faculty members perceived success rates as lower and grant sizes as less adequate to the costs of research. To sustain an ongoing research operation in an uncertain environment, researchers said they needed to write more proposals to ensure that they would secure sufficient funds. Similarly, short grant duration meant more frequent attempts to secure funding.

The researchers interviewed saw funding agencies as increasingly favoring larger, often interdisciplinary, center-type awards. They expressed a range of opinions about this trend. Some argued that it was largely a matter of fashion and that the "real" creative contributions in these larger enterprises occurred in relatively small collaborative units. In their view, these larger awards more often created superfluous overhead than the synergies that greater size and internal diversity are supposed to produce. Others argued that changing emphases in the funding agencies primarily reflected changes in the locus of research opportunities. They believed that the organization of research had needed to change accordingly to exploit these opportunities most effectively. In their view, for these larger projects, whether administered through newly created centers or existing administrative units, researchers would need to be prepared to incur both the increased administrative costs of building more complex and formal research organizations and the increased communication costs of cultivating shared research agendas among scientists from different disciplinary backgrounds.

Study informants stated that the movement toward larger research teams and interdisciplinary grants increased the costs of acquiring funding. Preparation of competitive proposals for these larger awards often necessitated developing research tools, protocols, and extensive preliminary data to demonstrate the viability of an approach. Researchers claimed that putting together the infrastructure for a major interdisciplinary effort also requires extensive communication among collaborators who, even at the proposal stage, need to develop a common intellectual vision and plan of work. Unlike proposals that aim to fund the ongoing research program of a single laboratory, these proposals involve more than the continuation of existing relationships. In addition, the planned organizational endeavors are large enough that they are not apt to be viable, even at a reduced scale, in the absence of funding, so that time and energy invested in an ultimately unsuccessful proposal might well lead nowhere. In contrast, when proposals for small grants involving one or two PIs are unsuccessful in their original form, they are more susceptible to various kinds of adaptation and reuse.

Many researchers perceived the funding agencies as increasingly risk averse, particularly when money was tight and success rates low. Funding agencies were also criticized as increasingly directive, in part because they were seen as driven more by internal priorities for research than by perspectives drawn from the wider research community. At the same time, some researchers said that funding agency staff turned over more frequently, making the agencies less able to sustain commitments and provide stable, long-term funding. Especially at the most prestigious universities, some researchers argued that federal efforts to distribute research funds more widely had adversely affected the quality of research.

In characterizing trends in U.S. funding patterns, several researchers familiar with research investments in other developed countries made suggestive comparisons. More than one researcher commented on the rigidity of European Union efforts to mandate multicountry, multidisciplinary research and saw U.S. efforts to encourage multidisciplinarity as more flexible. Likewise, some researchers praised the historic diversity of funding sources in the United States, which they saw as enabling varied perspectives and approaches to flourish. Many informants said that U.S. science was more competitive and open to new ideas than the European and Japanese systems, where researchers in select hierarchical positions were perceived to dominate funding. Some observers, however, claimed that European and Japanese efforts to open their systems to competition were bearing fruit, and even suggested that U.S. science might be suffering from an inability to plan effectively in an unstable, highly competitive funding environment. No clear message emerged from study interviews as to how the funding process could appropriately balance security and risk or whether other countries were moving to balance these better than the United States.

Regulatory Compliance

Many researchers reported that they spent significantly more time complying with government regulations than they had in the past. Depending on their fields of study, researchers cited different regulatory requirements as consequential. Health-related fields were perhaps the most strongly affected by compliance activities. Researchers mentioned patient privacy regulations, PI financial conflict of interests rules, institutional review boards for the protection of human research subjects, and animal care and use standards as all contributing to added time for compliance; many of these rules also affect research outside the medical area. In other fields, additional regulations were salient. Twice, for example, researchers who use satellites in their work mentioned increasingly stringent interpretations of security provisions in the

International Traffic in Arms Regulations as having made it harder for them to work with international collaborators.

In general, funding agencies have moved toward greater accountability and reporting requirements. Insofar as the agencies have emphasized larger grants to newly developed teams, they have taken a more active monitoring role to protect their investments.

Although senior faculty agreed that some work related to government regulation can readily be delegated to administrative personnel specializing in compliance who are not trained as researchers, they insisted that much of it requires an in-depth, substantive understanding of research and defies delegation. In addition, many claimed that federal agencies had become more reluctant to allocate grant funds to pay for administrative support, with the result that researchers had little alternative but to do necessary administrative work themselves. The study team heard this claim most often at an institution that had suffered adverse public comment more than a decade ago for alleged laxity in complying with federal rules for using facilities and administration funds. But the team also heard this at other universities, which had no special reasons for sensitivity to this issue.

Some of the increased administrative workload is probably better characterized as a matter of governance than of compliance. At several universities informants reported that faculty members had become more active in fashioning the university's approaches to governance issues than had been the case in the 1970s or early 1980s. Although involvement in utilization committees at hospitals or committees to set campus affirmative action policies may not be strictly a function of regulatory requirements, some informants characterized it as reflecting an environment in which faculty perceive administrative decisions as consequential and seek an active role in them.

The Global Environment

The role of U.S. research in the world's S&E journals is only partly a function of developments within the United States itself. Changes in research capacity in other countries are also relevant. This section discusses informants' perceptions of changing patterns of competition and cooperation between the U.S. research community and the research enterprise elsewhere around the world.

International Science

Almost all of the researchers interviewed said that research capacity in the major European countries, Japan, and the emerging Asian countries was improving substantially. Informants varied as to which individual countries they named and precisely how highly they rated them relative to the United States. In general, the United Kingdom, France, and Germany were most often mentioned as at or near parity with the United States; Japan was also often rated very highly, but occasionally was characterized as having failed to make significant strides. China and, to a lesser extent, India were seen as producing a substantially increased volume of reputable research, although neither was viewed as currently a competitor for world leadership. Smaller East Asian entities, including Singapore, South Korea, and Taiwan, were also mentioned as having substantially increased and improved their scientific output. In most large fields researchers viewed the United States as continuing to produce a greater volume of high-quality research than other parts of the world, but said the gap between the United States and other leading countries was shrinking.

Study informants cited various indicators of scientific improvement elsewhere in the world. A biomedical researcher claimed that U.S. scientists had been featured at the European meetings he attended in the early 1990s, but that Europeans now dominated these meetings. Similarly, a biochemist said that although 20 years ago one might have been able to ignore work performed abroad in her field, doing so would be unthinkable today. Scientists across the range of disciplines noted the increased presence in the major journals of articles by researchers at foreign institutions. At one university, the chief academic officer observed that letters from foreign scientists were forming a growing part of tenure and promotion files.

Informants pointed to several reasons why other countries' research contributions had improved, citing both increased resources available for research and institutional changes that facilitate effective use of those resources, notably:

- *Major investments in facilities and equipment.* Physical scientists were especially prone to emphasize investments in large facilities and satellite-based research, contrasting these investments with the relatively low funding priority that the United States, in their view, has given these fields. However, biologists also reported that infrastructure investments in the major developed countries had made biomedical science in these countries more competitive.
- *Improved selection and training of personnel.* Other nations have benefited from training their citizens at international centers of research excellence, often in the United States. Many of these researchers either return to their native countries or maintain strong professional ties to institutions in those countries, thus improving the research infrastructure. In addition, several researchers noted that in many countries where access to higher education historically had been more restricted than in the United States, higher education had become much more accessible to many segments of the population in the last two or three decades. They speculated that research in these countries had benefited from drawing on a wider talent pool.
- *Improved utilization and development of trained personnel.* Many informants noted that historic patterns of deference to hierarchical superiors had eroded in the national scientific institutions of other developed countries, though the study team heard quite different judgments about when, where, and how much this had occurred and how much difference remained between the United States and these countries. Consequently, younger researchers in these countries had experienced increased opportunities to achieve greater responsibilities and rewards and had been able to make correspondingly greater scientific contributions. However, the team also heard references to rigid personnel policies in European university systems and suggestions that these policies had forced productive researchers into retirement or caused them to relocate to U.S. universities.
- *Greater openness in competition for funding.* As noted above in the discussion of U.S. funding agencies, U.S. scientists perceived funding in other countries as becoming more open to competition and more strongly determined by merit. Some study informants said that in their fields the leading developed countries had always had a few world-class laboratories comparable to the best laboratories in the United States and that, historically, the U.S. advantage had derived from its large numbers of additional laboratories and research institutions that approached, but did not quite reach, international stature. They argued that these countries had improved mainly by developing additional research groups at the latter quality level, thereby creating a critical mass of high-quality research within their borders.

- *Greater access to shared research tools.* Electronically accessible international databases, software, and similar tools have enabled well-trained researchers to do better work even when they were not located in the best universities.
- *Strategic funding for emerging centers of excellence.* Some informants argued that other developed countries had deliberately concentrated funding in a few institutions to build centers of excellence, rather than spreading it among a large number of institutions. They claimed American political culture would have made this elitist strategy unacceptable, even though it might be scientifically productive.
- *Adoption or adaptation of U.S. models.* Several researchers, especially in environmental sciences, said that U.S. interdisciplinary teams had pioneered truly integrative collaborations, but that European and Japanese research organizations had learned from the U.S. experience and were continuing to do so. Others claimed that movement in other countries toward more egalitarian work practices and more competitive reward systems was influenced in part by U.S. practices.

Globalization

Almost all of the researchers interviewed agreed that research had become more global and less national in the period spanning 1988 to 2003; a few said it had been thoroughly global at the beginning of that period. One scientist characterized her colleague network as entirely international, and another said that distinctively national intellectual traditions were disappearing in his field. However, the general movement toward globalization in the research community had not erased differences among fields in the degree of globalization.

One indicator of globalization is the changing role of the English language. Already the dominant language of scientific discourse in the 1980s, English has become essentially universal since that time. Study informants reported that major international conferences were routinely held in English, regardless of whether English was the language of the host country. Leading journals on the European continent have moved toward publishing in English.

The trend toward more collaborative research includes more collaboration across national boundaries. Facilitated by better electronic communication, more frequent international meetings, easier international travel, and, in many cases, by government programs and incentives, this trend is evident in increased numbers of internationally coauthored articles. Likewise, administrators at one university observed that their institution had experienced a substantial increase in subawards to institutions in other developed countries.

Globalization also affects personnel. Graduate students and postdocs from other countries have become more common at U.S. universities. The job market for faculty members at all ranks has likewise become more international, though more so in some fields than in others and more at senior levels than junior ones.

Conclusion

As explained at the outset of this report, SRS intended its university visits to be exploratory. SRS does not believe that data such as these can yield either definitive descriptions of how academic S&E research has been changing or definitive explanations of the causes of the publication trends observed in the quantitative data. Moreover, data from interviews and meetings with knowledgeable informants are not very useful, even in an exploratory way, for considering some possible explanations (e.g., that article counts are affected by an aging researcher workforce that produces fewer articles per researcher).

Nonetheless, it may be useful, in concluding, to bring the descriptive generalizations from the university visits to bear on the trends SRS ultimately hopes can be explained and to identify issues for which more extensive or systematic data collection or analysis might be warranted.

The findings from the university visits suggest that changes in the role of peer-reviewed journals are unlikely to account for the trends observed in article counts. Throughout the period studied, peer-reviewed journals remained the major vehicle by which research findings were validated and scientists obtained credit for their contributions. According to the study informants, data on article counts are unlikely to mask or distort real changes in scholarly output, except, possibly, in computer sciences. If U.S. researchers figure less prominently in the journal literature, the reason does not appear to be because they are reporting their findings in ways that bypass the journals.

Because this study was prompted by the difference between publication trends in the United States and other countries, observations that may relate to national differences in research output are especially salient. Conversely, changes in research and publication practices that seem more likely to have relatively uniform effects on output worldwide, such as changes in computer software that make manuscript preparation easier, hold little promise for helping to explain variation among nations.

Perhaps the observation made most consistently and confidently by study informants is that the research done in other developed countries and in several emerging Asian economies has been getting better and more abundant. In their view, improved capacity overseas, more than changes in what Americans have been doing, likely accounts for the increased share of S&E papers from foreign institutions. In an expanding literature, they see a continuing, even growing, American presence, but more marked growth occurring in other countries.

Advances in communication have made the international scientific literature more accessible to researchers in other countries. In this regard, advances in electronic communication loom large. As potential contributors to the literature, researchers can take advantage of improved electronic communication to collaborate more easily with distant colleagues and submit papers online. As readers, they can receive papers from colleagues via e-mail, find information in electronic archives and databases, and access scientific communications that cannot be found in a local university library. But, beyond electronic communication, increased worldwide capacity to communicate in a common scientific language, English, has also played a role.

As the largest and most influential producer of scientific articles in the world and a nation whose native language is also the dominant language of science, the United States was already at the center of the worldwide system of scientific communication before these advances occurred. Thus, journals were already highly accessible to U.S.

researchers, both as contributors and as readers, at the outset of the period studied. Improvements in communication may have had a greater effect on the ability of researchers elsewhere in the world—especially those in nations or at institutions that were not prominent in research in the late 1980s—to keep up with their fields, produce research of a reasonable quality, and report their research in journals with a wider audience and a greater impact.

Institutional differences may also be affecting article counts. U.S. researchers perceive their universities and funding agencies as less attuned to quantitative measures of output and impact than their institutional counterparts in other countries. As a result, U.S. researchers may be less concerned with producing scholarly output in ways that score well on these measures. Study informants stressed the role of expert judgment in maintaining the commitment to quality in the U.S. system and saw the system as somewhat more oriented toward quality than in the past. They portrayed pressures toward scientific productivity as increasing, if anything, but as directed more toward enhanced quality than toward greater quantities of output. In contrast, many U.S. researchers interviewed saw other countries' efforts to improve research during the period under study as being increasingly driven by quantitative measures.

The study's findings provide little support for the idea that competing institutional demands are diverting faculty from research and publication. For the most part, informants said that neither teaching nor commercial activities were absorbing time that in the past would have been devoted to research and writing. Although some saw increased university concern about good teaching, and all agreed that institutional support for commercial activity was growing, faculty continued to believe that research was clearly the institutional concern that mattered most in shaping their behavior. It is possible, of course, that activities that compete with research for faculty time and attention, especially commercialization-related activities, have adverse effects on publication outputs that researchers themselves do not fully appreciate.

One of the most striking recent changes in how research is done has been the movement toward more collaborative work, and especially toward interdisciplinary and interinstitutional collaboration. Study data suggest that this trend can have either of two opposite effects on publication output. Insofar as it involves "complementary" collaborations that increase research output via a more rational division of labor, it should generate increased numbers of publications. However, insofar as the trend involves "integrative" collaborations that require extensive communication to synthesize different perspectives on a problem into a coherent piece of research, more people, money, and time may be required to produce a publishable article. It is possible that growth in publication output has slowed as a result of a movement toward integrative collaborations.

In the absence of solid data distinguishing the two kinds of collaboration, hypothesized relationships that turn on this distinction will be difficult to test. Yet, to interpret the significance in changes in publication output, it may be important to use relatively sophisticated understandings of the interplay among article counts, impact, collaboration, and interdisciplinarity. Some study informants suggested that successful integrative collaborations have had disproportionate impact on their fields and that the United States has been in the forefront of movement toward this type of collaboration. If U.S. researchers, compared with researchers in other countries, have been more rapidly increasing their investment of time and resources in this type of collaboration, this might affect article counts.

Another possibility, suggested by a reviewer commenting on an earlier draft of this report, is that the United States may experience "a productivity price associated with being in the leading position" in research worldwide. Insofar as research leadership requires personnel with the technical and interpersonal skills to forge successful integrative collaborations, such personnel may cost even more than personnel who are "merely" in the forefront of their specialties. Similarly, insofar as research leadership requires innovative use or development of state-of-the-art equipment, equipment costs may be even greater than for techniques that "merely" need the most advanced equipment available. Moreover, research in the "leading position" is more susceptible to failures and false starts that do not generate publications. To be sure, these costs are borne by leading research groups around the world; if they occur more often in the United States, they certainly do not occur exclusively in this country.

The effects of time and effort devoted to securing funding may also warrant further consideration. Some researchers said that in the United States competitive mechanisms intended to spur productivity sometimes and increasingly had had the opposite effect, even as other countries profited from introducing more such mechanisms. Similarly, although the study team heard indications that regulatory and governance burdens were increasing at U.S. universities, there was little to indicate whether the situation in other countries was different in this regard.

Appendix A. Universities Visited

Boston University

California Institute of Technology

Duke University

Harvard University

Stanford University

University of California, Los Angeles

University of Chicago

University of Illinois at Urbana/Champaign

University of North Carolina at Chapel Hill

Appendix B. Method

Participation in the study was voluntary, both for the institutions selected and for the individuals who chose to meet with the study team. At each institution, the team relied on assistance from a university executive responsible for research or graduate education—typically a vice president, dean, or provost—to arrange individual interviews and group meetings with faculty and administrators. The team requested interviews and meetings with people in certain broad disciplinary categories (e.g., social scientists, engineers) or administrative roles (e.g., heads of centers), but the university selected and recruited individuals in those categories. When members of the team held group meetings, they tried to bring together people with some common administrative or research experience—department chairs, for example, or biomedical researchers. Due to the time burden involved, two universities contacted expressed reluctance to host a visit, and the team decided to visit other universities instead.

There was probably some selection bias both in who the universities invited to meet with team members and who accepted the invitations. Although the team emphasized the value of talking with researchers across the range of the sciences, it is possible that more of those interviewed had some kind of connection to the National Science Foundation (NSF) or the kinds of science it supports than would have been the case had they been selected strictly at random. In addition, some informants, including several advocates of open-access publishing, may have chosen to participate because of strongly held views about certain aspects of scientific publication.

It is doubtful, however, that selection biases substantially distort the information received. The issues most central to the study are largely factual, including, for example, changes in research collaboration and interdisciplinarity, the effects of new information technologies, the balance between quality and quantity in university rewards for research, and trends in the amount and quality of research done overseas. These issues are generally not so value or policy laden as to motivate participation or skew perceptions. Moreover, variations in opinions (e.g., about the merits of "big science") did not appear to be closely related to differences in factual observations (e.g., about the growth of "big science").

The study informants were mainly senior researchers and administrators, and their perspectives were doubtless affected by their seniority. Furthermore, their perspectives on how research and publication functioned in the past were developed at times when, for the most part, they were in more junior positions. In discussing differences over time, a few informants appeared concerned that changes in their own roles as they assumed more senior status might distort their perceptions of changes in the research and publication environment. Most did not appear troubled by this issue, and some, when it arose, professed confidence that they could distinguish between these two different reasons for perceived changes. It is doubtful that the value of informants' observations was seriously compromised by this potential bias, in part because the study team sought to question informants in ways that probed the relationship between seniority and publication-related behavior. Commenting on a draft of this report, one reviewer noted that it appeared to stress relatively recent developments more than changes that occurred early in the period under study. It is certainly possible that study informants' recollections involve a bias toward recent changes.

In any event, any biases that affect the frequency with which the team heard different observations or perspectives are not likely to be consequential. Beyond making relatively broad statements about frequency—"some," "many," "a few"—the study team did not analyze the data quantitatively. The data are presented as the insights and observations of knowledgeable informants about the parts of the research and publication process with which they are most familiar. These insights and observations function less to prove propositions than to sensitize the science and engineering (S&E) community to the dynamics of research and publication and the contexts in which they occur, suggesting hypotheses that can be tested in more systematic research and ways to interpret relationships found in the quantitative data.

Interviews and meetings were semistructured; they followed a general pattern, but the interviewer or group leader made occasional strategic deviations from it when warranted. The study team used written topical guides to facilitate coverage of relevant topics and suggest response probes. These guides were pretested in interviews and focus groups with university-based scientists and engineers who were working at NSF on a temporary basis. The team developed different guides for people in different administrative positions, and different guides for interviews and group meetings, but the overlap among the various guides was substantial. With some informants, the team members were able to ask practically all of the questions in the guide and to pose them in the sequence in which they were listed. In these cases, the guide functioned almost like a questionnaire in a structured interview. More often, however, the guide provided only an approximate order for raising issues, a suggested question wording, and a reference to ensure that major issues were not neglected. Typically, informants discussed several related topics in response to a question, and probes led them to discuss still other issues. In addition, questions were omitted when it became apparent that informants either lacked relevant experiences (e.g., participation in international collaborations) or did not treat particular distinctions (e.g., among different kinds of collaborators) as important. Sometimes, too, time limitations forced team members to be selective in the questions raised. Appendix C provides examples of interview and meeting guides.

The study team tried to divide its time evenly between individual interviews and group meetings. The two have complementary advantages. Interviews provided more depth about particular circumstances and individual perspectives, but group interaction probed, validated, and refined individual observations. The difficulty of arranging group meetings meant that somewhat more time was spent in individual sessions and that groups often contained fewer than the 6–10 participants requested.

Three researchers from NSF's Division of Science Resources Statistics trained in either sociology or economics conducted the interviews and meetings. All had substantial familiarity with research and publication in S&E and with how universities are administered. Two had acquired extensive interviewing experience earlier in their research careers. The third participated with an experienced colleague in most of the pretest interviews at NSF and in the first two university visits, where the two researchers conducted the interviews and meetings jointly. Each of the other visits was made by a single researcher. Interviewers took notes during the sessions they conducted and also taped almost all of them. The observations that the different members of the research team recorded and the impressions they received were substantially similar; the team has no reason to believe that which individual conducted an interview or meeting had any meaningful impact on the data that were generated.

Appendix C. Interview Guides

This appendix contains interview guides for interviews with S&E faculty, department chairs, and university level officials (i.e., provosts, vice presidents for research). With minor modifications, these guides were used for focus groups and for interviews with similarly situated persons. The department chair guide, for example, was modified for use with center directors.

Faculty Interview

Background

What are your research areas?

Please describe your research career. (Institutional affiliations, collaborations, major lines of research).

Please list the 3–5 leading journals in your area of research—the journals in which it would be most desirable to have a paper appear.

Research Environment

Has the way that research is done in your field changed in the last decade? How?

Which of the following have changed, and in what ways?

role of/need for equipment and infrastructure

role of/need for access to postdocs

role of/need for access to technicians and other professional lab personnel

role of/need for access to graduate students

role of/need for access to undergraduates

type of work that contributes to a publication

need for greater/lesser amount of grant funds

sources of available grant funds

funding agencies' emphasis on more basic/more applied research

time investment in writing proposals/securing funding

Have patterns of collaborative work changed in your field in the last decade? How?

role of/need for collaborators?

type of collaborators needed?

number of people/groups in a collaboration?

more interdisciplinary?

more international?

less shaped by prior membership in a single lab?

Have possibilities of commercialization changed the way people do research in your field? How?

One hears a lot about the globalization of research. Is the research community becoming more global in your field? In what ways?

How has globalization affected your own work?

How has it affected your colleagues' work?

Publication Practices

How have publication practices changed?

What has the Internet done to change the dissemination of research findings?

Have the rewards for publication changed in any way?

Is there more/less emphasis on quantity of publication?

Is there more/less emphasis on quality of publication?

Is there more/less emphasis on quality of the journal in which a paper appears?

Have there been changes in the way that universities weigh publications in tenure and promotion decisions?

Have there been changes in the ease or difficulty of publishing in different outlets?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops outside the U.S.? If so, has this affected what eventually gets published?

Have there been changes in the degree to which labs reserve data so that graduate students or postdocs can publish from it later?

Have there been changes in scientists' tendency to engage in "salami publishing"? How? Why?

Have journals' practices regarding page charges changed in ways that affect researchers' publication practices?

Have there been changes in scientists' tendency to publish collaborative papers? How? Why?

How have changes in the kinds of collaborations in which researchers engage affected the kind of work they publish?

For each of the following kinds of publications, have there been changes in their perceived value in your field?

coauthored publications

multiauthored publications

multiauthored publications with many (10 plus) authors

coauthorship with a senior colleague or dissertation advisor

coauthorship with a junior colleague or student

coauthorship with colleagues at your institution

coauthorship with colleagues at other U.S. institutions

coauthorship with colleagues at foreign institutions

In what ways, if any, have journal reviewing and publishing practices changed in the last decade?

more/less competitive and rigorous

more/fewer outlets in your field

greater/lesser quality of individual publications

more/less work required to get a paper published

more/less difficult to get a paper published in a quality journal

greater openness to publishing work by foreign scientists

In what ways, if any, have scientists in your field changed their practices regarding reporting research in outlets other than refereed journals in the last decade? Why the change?

books

book chapters

Internet publication

conference proceedings

Have researchers' practices in submitting papers for publication changed in the last decade (e.g., regarding quality of journal, scope of the paper)?

Has a journal's inclusion in the Science Citation Index become more/less important for researchers deciding where to submit papers for publication?

Has the premium for publishing in the top 3–5 journals in your area changed? Increased or decreased?

University Work Environment

In your experience, have expectations/practices regarding teaching changed in the past decade? In what ways?

Have changes in expectations/practices for teaching affected publication practices? How?

In your experience, have expectations/practices regarding university service changed in the past decade? In what ways?

Have changes in expectations/practices for university service affected publication practices? How?

In your experience, have expectations/practices regarding community service changed in the past decade? In what ways?

Have changes in expectations/practices regarding community service affected publication practices? How?

In your experience, have expectations/practices regarding commercialization of research changed in the past decade? How?

How have changes in expectations/practices regarding commercialization affected publication practices? Do researchers now withhold things that in the past would have resulted in publications?

In your experience, have expectations/practices regarding consulting with industry changed in the past decade? With government? In what ways?

Have changes in expectations/practices regarding consulting affected publication practices? How?

Have changes in the kinds of graduate students available in your field (e.g., quality, nationality, career aspirations) affected publication practices? In what ways?

Have changes in the kinds of postdocs available in your field (e.g., quality, nationality, career aspirations) affected publication practices? In what ways?

Have changes in the availability of other kinds of research personnel (technicians, undergraduates, etc.) affected publication practices? In what ways?

Have funding agencies changed their practices in ways that affect how many or what kinds of publications researchers produce?

Related Practices

Have standards for what contributions warrant authorship changed in your field in the last decade? In what ways?

In what ways, if any, have citation practices (frequency of citing publications, types of publication cited) changed in the last decade?

Is it your impression that publication practices for scientists in different institutional sectors (academia, industry, government, different kinds of academic institutions) have become more similar or more different over the last decade (e.g., in what researchers do, in what is valued)?

Is it your impression that publication practices in other nations have become more similar to or more different from those in the U.S. over the last decade? In what ways?

Has there been a change in publication practices by foreign scientists and groups in your area? In what way?

What, in your view, have been the major causes of this change?

Department Chair Interview

Background

What are your research areas?

Please describe your research career. (Institutional affiliations, collaborations, major lines of research.)

Please describe the main areas of concentration of your department within your field.

Please list the 3–5 leading journals in your department's area of research—the journals in which it would be most desirable to have a paper appear.

Research Environment

Has the way that research is done in your field changed in the last decade? How?

Which of the following have changed, and in what ways?

> role of/need for equipment and infrastructure
>
> role of/need for access to postdocs
>
> role of/need for access to technicians and other professional lab personnel
>
> role of/need for access to graduate students
>
> role of/need for access to undergraduates
>
> type of work that contributes to a publication
>
> need for greater/lesser amount of grant funds
>
> sources of available grant funds
>
> funding agencies' emphasis on more basic/more applied research
>
> time investment in writing proposals/securing funding

Have patterns of collaborative work changed in your field in the last decade? How?

> role of/need for collaborators?
>
> type of collaborators needed?
>
> number of people/groups in a collaboration?

more interdisciplinary?

more international?

less shaped by prior membership in a single lab?

Have possibilities of commercialization changed the way people do research in your field? How?

One hears a lot about the globalization of research. Is the research community becoming more global in your field? In what ways?

Have centers assumed a more important role in research relative to university departments? How has this affected scientific publication?

Publication Practices

How have publication practices changed?

What has the Internet done to change the dissemination of research findings?

Have the rewards for publication at your university changed in any way?

Is there more/less emphasis on quantity of publication?

Is there more/less emphasis on quality of publication?

Is there more/less emphasis on quality of the journal in which a paper appears?

Has the premium for publishing in the top 3–5 journals in an area changed? Increased or decreased?

Has a journal's inclusion in the Science Citation Index become more/less important for assessing publications at your university?

Have citations to a researcher's publications (impact factors) changed in importance?

Have there been changes in the way your university weighs publications in tenure and promotion decisions?

How does your university handle differences in publication practices among fields when you assess faculty productivity? How has this changed over time?

To what degree is this a source of concern among faculty coming up for tenure and promotion? Among department chairs?

How does your university handle emerging research practices (e.g., collaborative, interdisciplinary, Internet-based) in tenure and promotion decisions?

Have there been changes in the ease or difficulty of publishing in different outlets?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops outside the U.S.? If so, has this affected what eventually gets published?

Have there been changes in the degree to which labs reserve data so that graduate students or postdocs can publish from it later?

Have there been changes in the scope of the least publishable unit? How? Why?

Have journals' practices regarding page charges changed in ways that affect researchers' publication practices?

Have there been changes in scientists' tendency to publish collaborative papers? How? Why?

How have changes in the kinds of collaborations in which researchers engage affected the kind of work they publish?

For each of the following kinds of publications, have there been changes in their perceived value in your field?

- coauthored publications
- multiauthored publications
- multiauthored publications with many (10 plus) authors
- coauthorship with a senior colleague or dissertation advisor
- coauthorship with a junior colleague or student
- coauthorship with colleagues at your institution
- coauthorship with colleagues at other U.S. institutions
- coauthorship with colleagues at foreign institutions

In what ways, if any, have journal reviewing and publishing practices changed in the last decade?

- more/less competitive and rigorous

more/fewer outlets in your field

greater/lesser quality of individual publications

more/less work required to get a paper published

more/less difficult to get a paper published in a quality journal

greater openness to publishing work by foreign scientists

In what ways, if any, have scientists in your field changed their practices regarding reporting research in outlets other than refereed journals in the last decade? Why the change?

books

book chapters

Internet publication

conference proceedings

Have researchers' practices in submitting papers for publication changed in the last decade (e.g., regarding quality of journal, scope of the paper)?

Publication/Productivity Measurement

Which of the following measures of research productivity and quality do you use?

1. School or department-level publication counts
    a. Distinguish peer-reviewed journals from other publications?
    b. Distinguish ISI journals from others?
    c. Distinguish journals by impact factors?
    d. Distinguish selected named journals?

2. School or department-level citation data
    a. For journals in which researchers publish
    b. For articles researchers publish

3. Quantitative data relating to other kinds of research activity
    a. Books, book chapters, conference papers
    b. Conference appearances
    c. Reviewer, conference organizer, and other research-related roles

d. Digital or preprint archives

e. Contributions to databases (e.g., genomic)

f. Other

What other productivity and quality measures do you use?

How do departmental measures/criteria differ from university-level measures/criteria?

Has the relative emphasis on quantitative and qualitative (e.g., letters) measures changed in the past two decades? In what ways?

University Work Environment

In your experience, have expectations/practices regarding teaching changed in the past decade? In what ways?

Have changes in expectations/practices for teaching affected publication practices? How?

In your experience, have expectations/practices regarding university service changed in the past decade? In what ways?

Have changes in expectations/practices for university service affected publication practices? How?

In your experience, have expectations/practices regarding community service changed in the past decade? In what ways?

Have changes in expectations/practices regarding community service affected publication practices? How?

In your experience, have expectations/practices regarding commercialization of research changed in the past decade? How?

How have changes in expectations/practices regarding commercialization affected publication practices? Do researchers now withhold things that in the past would have resulted in publications?

In your experience, have expectations/practices regarding consulting with industry changed in the past decade? With government? In what ways?

Have changes in expectations/practices regarding consulting affected publication practices? How?

Have changes in the kinds of graduate students available in your field (e.g., quality, nationality, career aspirations) affected publication practices? In what ways?

Have changes in the kinds of postdocs available in your field (e.g., quality, nationality, career aspirations) affected publication practices? In what ways?

Have changes in the availability of other kinds of research personnel (technicians, undergraduates, etc.) affected publication practices? In what ways?

Have funding agencies changed their practices in ways that affect how many or what kinds of publications researchers produce?

Related Practices

Have standards for what contributions warrant authorship changed in your field in the last decade? In what ways?

In what ways, if any, have citation practices (frequency of citing publications, types of publication cited) changed in the last decade?

Is it your impression that publication practices for scientists in different institutional sectors (academia, industry, government, different kinds of academic institutions) have become more similar or more different over the last decade (e.g., in what researchers do, in what is valued)?

Is it your impression that publication practices in other nations have become more similar to or more different from those in the U.S. over the last decade? In what ways?

Has there been a change in publication practices by foreign scientists and groups in your area? In what way?

What, in your view, have been the major causes of this change?

Provost Interview

Please sketch your background/history at this institution.

University Work Environment

In your experience, have expectations/practices regarding research changed in the past decade? In what ways?

In your experience, have expectations/practices regarding teaching changed in the past decade? In what ways?

Have changes in expectations/practices for teaching affected publication practices? How?

In your experience, have expectations/practices regarding university service changed in the past decade? In what ways?

Have changes in expectations/practices for university service affected publication practices? How?

In your experience, have expectations/practices regarding community service changed in the past decade? In what ways?

Have changes in expectations/practices regarding community service affected publication practices? How?

In your experience, have expectations/practices regarding consulting with industry changed in the past decade? With government? In what ways?

Have changes in expectations/practices regarding consulting affected publication practices? How?

Research Environment

Has the way that research is done at your university/in American universities changed in the last two decades? How?

Has research become more collaborative? How (e.g., within the university, across universities)? How has this affected scientific publication?

Has research become more interdisciplinary? How (e.g., across broad domains of science, within broad domains)? How has this affected scientific publication?

One hears a lot about the globalization of research. Is the research community becoming more global? How has this affected publication practices at your university?

Have centers assumed a more important role in research relative to university departments? How has this affected scientific publication?

In your experience, have expectations/practices regarding commercialization of research changed in the past decade? How? How has this affected scientific publication? Do researchers now withhold things that in the past would have resulted in publications?

Has the availability of good graduate students changed (e.g., quality, nationality, career aspirations)? Has this affected publication practices? In what ways?

Has the availability of good postdocs changed (e.g., quality, nationality, career aspirations)? Has this affected publication practices? In what ways?

Has the availability of other kinds of research personnel changed (technicians, undergraduates, etc.)? Has this affected publication practices? In what ways?

Have funding agencies changed their practices? In what ways (basic/applied emphases, different mix of agency sources, different funding levels, different administrative monitoring practices, harder/easier to get funds)? How has this affected how many or what kinds of publications researchers produce?

Publication Practices

What has the Internet done to change the dissemination of research findings?

Have the rewards for publication (at your university, in academic research) changed in any way?

Is there more/less emphasis on quantity of publication?

Is there more/less emphasis on quality of publication?

Is there more/less emphasis on quality of the journal in which a paper appears?

Has the premium for publishing in the top 3–5 journals in an area changed? Increased or decreased?

Has a journal's inclusion in the Science Citation Index become more/less important for assessing publications at your university?

Have citations to a researcher's publications (impact factors) changed in importance?

Have there been changes in the way that your university weighs publications in tenure and promotion decisions?

How does your university handle differences in publication practices among fields when you assess faculty productivity? How has this changed over time?

To what degree is this a source of concern among faculty coming up for tenure and promotion? Among department chairs?

How does your university handle emerging research practices (e.g., collaborative, interdisciplinary, Internet-based) in tenure and promotion decisions?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops?

Have there been changes in the emphasis on delivering papers/presentations at conferences and workshops outside the U.S.? If so, has this affected what eventually gets published?

Have there been changes in the degree to which labs reserve data? (So that graduate students or postdocs can publish from it later? For reasons relating to patenting or commercialization?)

Have there been changes in the least publishable unit? How? Why?

Have there been changes in scientists' tendency to publish collaborative papers? How? Why?

For each of the following kinds of publications, have there been changes in their perceived value at your university?

coauthored publications

multiauthored publications

multiauthored publications with many (10 plus) authors

coauthorship with a senior colleague or dissertation advisor

coauthorship with a junior colleague or student

coauthorship with colleagues at your institution

coauthorship with colleagues at other U.S. institutions

coauthorship with colleagues at foreign institutions

Have scientists at your university changed their practices regarding reporting research in outlets other than refereed journals in the past two decade? In what ways? Why the change?

books

book chapters

Internet publication

preprint archives

conference proceedings

Publication/Productivity Measurement

Which of the following measures of research productivity and quality do you use?

1. School or department-level publication counts
    a. Distinguish peer-reviewed journals from other publications?
    b. Distinguish ISI journals from others?
    c. Distinguish journals by impact factors?
    d. Distinguish selected named journals?

2. School or department-level citation data
    a. For journals in which researchers publish
    b. For articles researchers publish

3. Quantitative data relating to other kinds of research activity
    a. Books, book chapters, conference papers
    b. Conference appearances
    c. Reviewer, conference organizer, and other research-related roles
    d. Digital or preprint archives
    e. Contributions to databases (e.g., genomic)
    f. Other

What other productivity and quality measures do you use?

Has the relative emphasis on quantitative and qualitative (e.g., letters) measures changed in the past two decades? In what ways?

Related Practices

Have standards for what contributions warrant authorship changed in your field in the last decade? In what ways?

In what ways, if any, have citation practices (frequency of citing publications, types of publication cited) changed in the last decade?

Is it your impression that universities in other countries are changing their practices in ways that affect how their scientists publish? In what ways?

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