RESEARCH FUNDING

Science Funding and Short-Term Economic Activity

Expenditures from grant funds support many different types of workers and vendors across the nation.

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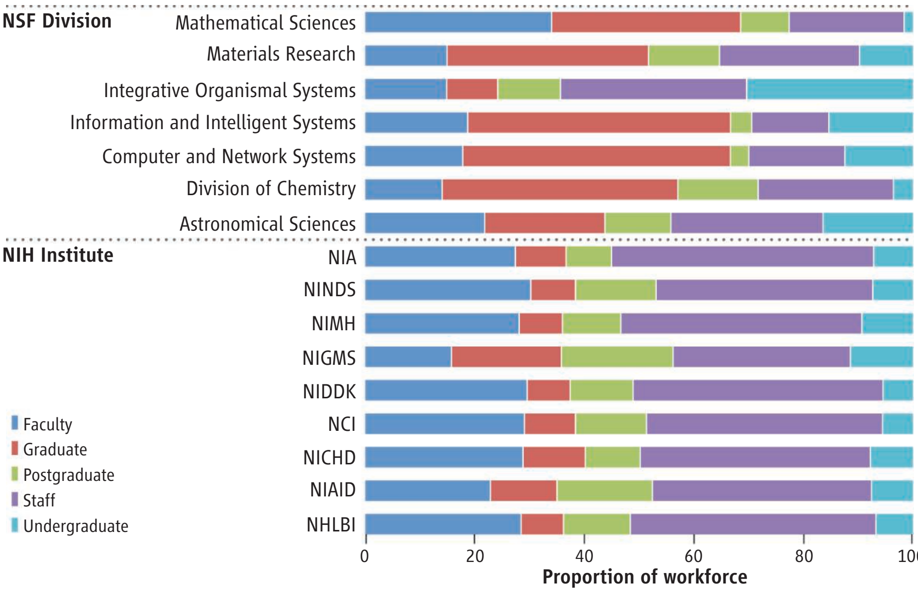
There is considerable interest among policy-makers in documenting short-term effects of science funding. A multiyear scientific journey that leads to long-term fruits of research, such as a moon landing, is more tangible if there is visible nearer-term activity, such as the presence of astronauts. Yet systematic data on such activities have not heretofore existed. The only source of information for describing the production of most science is surveys that have been called "a rough estimate, frequently based on unexamined assumptions that originated years earlier" (*1*).

But although science is complicated, it is not magic. It is productive work. Scientific endeavors employ people. They use capital inputs. Related economic activity occurs immediately. Data characterizing these activities can be directly captured through the financial and payroll records of research organizations and have been used in other arenas, such as labor policy. Our data provide the first detailed information about initial inputs to the publicly funded scientific enterprise and lay the foundation to trace subsequent results (*2*).

These new data were initially generated in response to the mandate put in place by the 2009 American Recovery and Reinvestment Act, also known as the stimulus package, which required that recipients of stimulus funds document the resulting jobs created and retained. In response, almost 100 U.S. universities and five federal agencies, with the support of the Federal Demonstration Partnership, established the STAR METRICS data program. The goal of the program was to document not just short-term, but also longer-term, results of scientific activity and to use automated approaches to do so (*2*). The first tranche of rich data are drawn directly from university personnel and financial administrative records that track actual expenditures of all active federal projects. These data provide project-level information about the occupations of the part-time and full-time workforce paid on each funded grant and about the purchases made from vendors who supply scientific researchers. Neither of these types of information have reliably been available before (*3*, *4*).

The results reported in this paper represent an analysis of 2012 expenditure data from nine Committee on Institutional Cooperation (CIC) universities participating in the emerging UMETRICS initiative—Michigan, Wisconsin, Minnesota (Twin Cities), Ohio State, Northwestern, Purdue, Michigan State, Chicago, and Indiana [see supplementary material (SM) for full details on data and analyses]. These universities received about $7 billion in research and development (R&D) funding from all sources in 2012; 56% of that came from federal government sources (*5*). In the aggregate, the 15 institutions that make up the CIC receive 8 to 10% of all federal research dollars. The majority of these institutions are large, Midwestern public universities. Hence, they are not representative of all recipients of federal funds. However, it is unlikely that the type of science that is conducted with those funds is markedly different from that conducted at many other major research universities, and they provide a window into a large portion of federal research activity in the era of tightening federal budgets. Moreover, the 2012 data we analyzed reflect expenditures from federal funds obligated over multiple prior years. These data thus offer a different, and possibly smoother, picture than is apparent in the often volatile annual federal-funding cycle.

Our initial analysis of all expenditures supported by federal funding to these nine CIC institutions—monies from some 30 agencies—shows that the production of science is complex but eminently traceable. We document reliance on a wide variety of inputs, including a heterogeneous mix of skills



Differences in workforce composition in projects funded by NSF divisions and NIH institutes. NIA, National Institute on Aging; NINDS, National Institute of Neurological Disorders and Stroke; NIMH, National Institute of Mental Health; NIDDK, National Institute of Diabetes and Digestive and Kidney Diseases; NICHD, Eunice Kennedy Shriver National Institute of Child Health and Human Development; NIAID, National Institute of Allergy and Infectious Diseases; NHLBI, National Heart, Lung, and Blood Institute. (See SM.)

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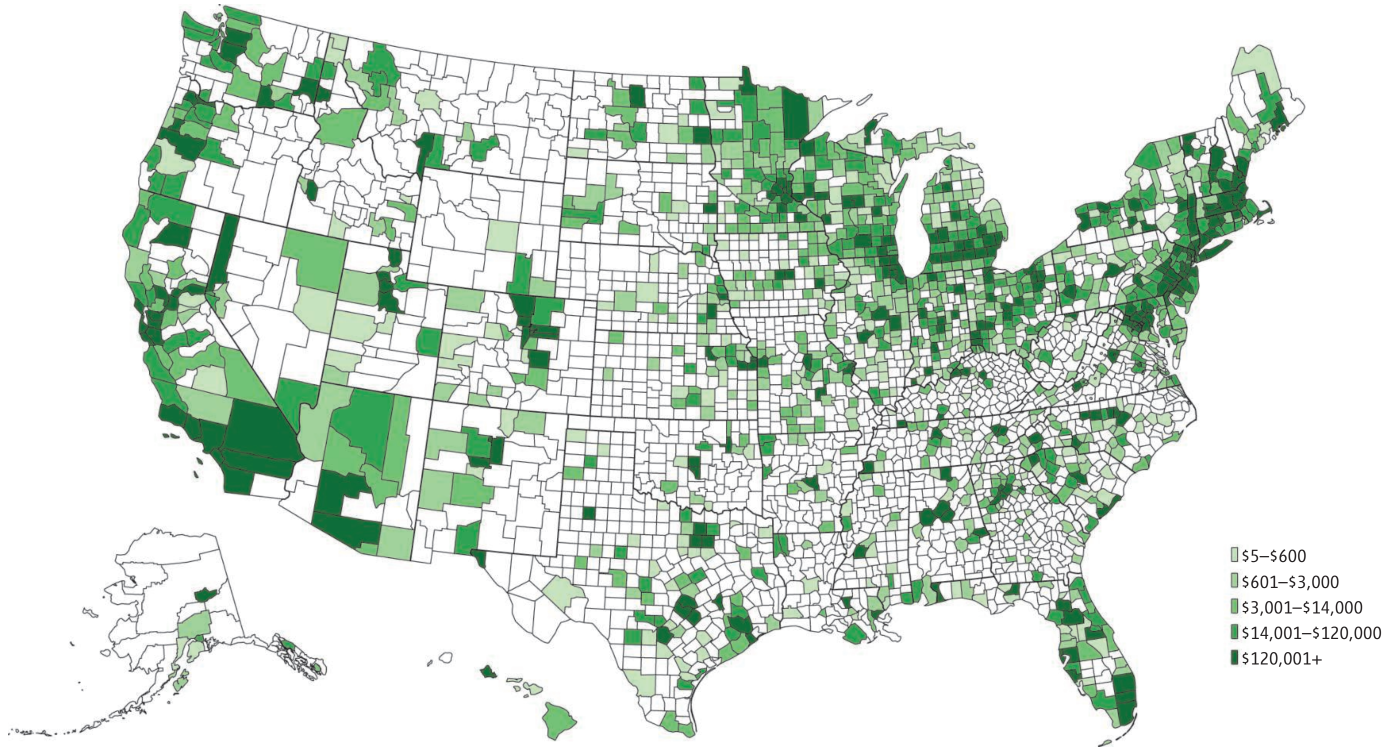

The geographic distribution of vendor and subaward expenditures. (See SM.)

(embodied in numerous students, postdocs, and research staff), as well as diverse goods and services purchased locally, within the institution's home state, and nationally. More detailed analysis of projects supported by two major science agencies [National Institutes of Health (NIH) and National Science Foundation (NSF)] reveals the need for extensive research at the levels of the individual grant and research group. That work will yield better knowledge about the process of scientific production while illuminating short-term consequences of changes in funding.

Of course, science funding is not primarily a jobs or economic stimulus program. The full public value of federal R&D rests on its long-term contributions to human knowledge and economic growth. The short-term activity that we document here results from the process of scientific work and should not be confused with the long-term benefits generated by the products of research.

Characterizing the Scientific Workforce

Although the question of whether federal research grants represent a form of public assistance for unproductive professors is beyond our purview, at least part of the claim (*6*) that federal funding primarily supports faculty "welfare queens in white lab coats" finds little support in these data. The people employed to conduct research on these campuses bring diverse types of skills to a wide range of jobs. Many are students learning the trade of science. Faculty researchers account for fewer than one in five of the individuals supported by federal funding. About one in three workers is either a graduate or an undergraduate student. One in 3 is either research staff or a staff scientist, and about 1 in 10 is a postdoctoral fellow.

Composition of the workforce on projects supported with funds from different sources can vary dramatically. Support from the NIH is substantial: The agency funds, in whole or in part, almost 40% of the individuals working on federally funded research projects we examined. The NSF supports just over 21%, whereas the Department of Education supports under 10%. Those numbers mask disparate workforce effects. NIH grants touch more than 50% of federally funded postdoctoral fellows, but only 24% of graduate students and 22% of undergraduates. By contrast, NSF dollars pay wages to over 35% of federally funded graduate students, 22% of undergraduates and fewer than 20% of postdoctoral fellows. It is not surprising that almost 25% of the undergraduates we observed work in some capacity on research grants funded by the Department of Education. One possible source of heterogeneity in the composition of the scientific workforce and in the mix of research and training could be differences in the missions of funders (*7*).

Another source of heterogeneity is the substantial variability in workforce composition across scientific areas (see the chart). Grants funded by NIH Institutes like the National Cancer Institute (NCI), which typically require the use of high-technology equipment, are more likely to rely on research staff. In contrast, grants from the National Institute of General Medical Sciences (NIGMS)—nearly 15% of which are training grants—rely more on graduate students and postdocs. Grants to chemists rely more on graduate students; those to mathematicians reach more faculty.

Untangling the reasons for empirical variations in the nature of the science, the type of the equipment that is used, and the size of the grants that each lab receives requires attention to the technical demands of different research areas, the orientations and rules of particular funders, and the strategies investigators deploy to fund and pursue their intellectual agendas. These variations seem likely to have substantial effects on research, training, and the social outcomes of science. Although these results may be intuitively obvious to scientists and students of science, this new evidence provides a systematic basis to quantify that intuition can rigorously inform policy-makers on the processes of science.

For example, empirical analyses of these rich data could help inform training policy. Recent reports suggest that graduate students' ability to complete their degrees and

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move into a permanent position depends on federal support. We also know that increases in training time are likely to have a chilling effect on the next cohort of scientists as greater opportunity costs reduce the numbers of people willing to embark on and complete scientific training (*3*). Empirical analyses that systematically link modes of training support to completion time and future matriculations can inform more effective policies to develop the scientific workforce. Empirical analyses could also inform policy decisions about different funding structures. Changes in funding to support disciplinary rather than interdisciplinary research or shifts from lab-based to center-based mechanisms are likely to change the type of workforce that is funded, as well as the mix of subsequent outcomes. Investing in building empirical evidence about the contribution of each of these factors would provide important evidence for policy-makers as they ponder the appropriate level and structure of federal support for science.

National Economic Reach

These data also shed light into the amount spent on goods and services from those subcontractors and vendors that provide inputs into the production of science. In 2012, the nine CIC institutions spent almost $1 billion of research expenditures on goods and services from U.S. vendors and subcontractors. Of those expenditures, more than 16% went to vendors in the university's home county, over 16% more in the rest of the home state, and the balance to vendors across the United States (see the map).

Both common sense and careful research dictate that science requires tangible and intangible inputs produced by organizations in a wide range of industries—grants buy mice and telescopes, reagents and computers (*4*). When we examined the vendors for many grants, we expected to see purchases from well-known large firms, and we did. But we were struck by two new sets of facts as we examined the Web sites of some of the tens of thousands of vendors which supplied research inputs. First, we were surprised by how many were small, niche high-technology companies. The important role of small, specialized companies in the scientific ecosystem is important and easy to miss as the presence of small businesses in complicated national markets can go largely undetected. Second, vendor Web sites suggest that many small businesses leverage the capacity they develop in supporting federally funded science to build new products and services. The role that science funding plays in stimulating innovation on the part of suppliers is also not well documented and understood.

More nuanced analyses of the effects federal grant purchases exert on the productivity of vendors represent a second, policy-relevant way that research using these data could shed light on both short-run and longer-term economic effects of federal R&D funding. If, as our analysis suggests, the process of scientific research supports organizations and jobs in many of the high skill sectors of our economy, rapid changes in funding could have substantial downstream consequences. In addition, the effects are likely to be national, rather than local (see the second figure).

The purchases can be substantial, but clearly depend on the nature of the research and probably the size and structure of the grant, as well as the rules of the funding agency. When we examined differences in spending within the research university's home state, we found different patterns depending on the source of funding. When scientists funded by NSF's mathematical sciences division purchase goods and services, they are much more likely to purchase within their home state; researchers funded by NCI tend to purchase materials from out of state, perhaps where specialized equipment vendors are located. The substantial variations across fields and funders are striking and merit much more study.

Although we currently lack (but expect these data to stimulate) the capacity to fully explain the sources and implications of these findings, our analysis indicates how scientific activity reverberates in unexpected ways through high-skill industries concentrated far away from a grant's recipient. A deeper analysis of expenditures of all institutions using, e.g., Census Bureau data, could be used by policy-makers to quantify how science funding drives innovation in suppliers of scientific equipment on the demand side.

Evidence Rather Than Anecdotes

Fortunately, the empirical foundations for science policy are being built by behavioral and social scientists across the world (*7*, *8*). Universities as far apart as the University of Melbourne and the Universidad Complutense de Madrid are exploring similar systems. There is first-rate work being done using data to document the effects of different access policies on research and innovation (*9*), or of the variability of funding on scientific output (*10*).

Our data contribute to this burgeoning movement by documenting short-run scientific activity and by providing evidence about the multifaceted, widespread nature of that activity. In particular, our data indicate the complexity of estimating the short-term effects of changes in scientific funding. It is important to note that any effort to rigorously quantify such effects requires information about how changes will be allocated across agencies and programs; estimates about how states, private funders, performers and researchers would respond; and assumptions about what would otherwise happen with science funds. The impact on competitiveness of vendors and subcontractors would also need to be taken into account. Based on our analysis of the grant funded workforce at these institutions, it seems clear that the consequences of funding cuts or the benefits of increases would fall disproportionately on trainees and staff segments of the scientific workforce who constitute much of our future capacity for cutting-edge R&D.

Decisions about the allocation of resources for research are made every year in every country. It is time the scientific community provided evidence rather than anecdotes so that policy-makers can assess the consequences of their decisions. The contribution of the UMETRICS initiative, and the database that underpins it, is to provide the foundations of such evidence that can be used not just in the United States but in other countries across the world.

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Supplementary Materials

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