Policy-Relevant Science: The Depth and Breadth of Support Networks

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Abstract. Proponents of basic science argue that objective scientific understanding can inform improvement in public policy. We gather data on scientific research cited in official benefit-cost analyses produced by US federal regulatory agencies to justify policy decisions between 2008 and 2012. We construct a science-policy network in which benefit-cost analyses and the studies they cite are the nodes, and citations represent the edges. We assess two features of each scientific publication in the network; how frequently is it used; and how broadly it spans across the network, as measured by betweenness centrality. We ask which author affiliations and funders are associated with the best-cited and farthest spanning publications. Elite universities and major government funders support publications that are most heavily cited, but the farthest spanning articles are written by scientists with non-academic affiliations and sponsored by non-governmental funders. These results suggest that bias towards academically affiliated investigators should be scrutinized by major funding organizations if a major objective is to support science that is used by policymakers.

Keywords: Scientometrics · Policy networks · Regulation

1 Introduction

Science improves knowledge of the physical, biological, and social worlds and contributes to society's betterment through industrial innovations and improved public policy. Policymakers use science in various ways to reach policy decisions [27], yet the mechanisms by which science is engaged and its contributions to policy outcomes are poorly understood. Allegations of manipulation and misuse are rampant [3,8]. Furthermore, while the quality of science is the premier

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concern of the scientific community, research on the applicability of scientific findings to public policymaking has been underway for decades, with a central challenge being the ability to trace the direct links between policy and science [18]. Recently-developed data on scientific citations in the benefit-cost analyses produced in the process of making significant federal regulations in the U.S. [9–11] offers a promising approach to directly connecting policy and science. This approach to measuring science use in public policy has been also been followed in the study of sub-national government in the U.S. [19]. In this article, we examine the properties of policymakers' invocation of science in justifying a broad range of regulatory policy decisions over time through the lens of a new policy-science network dataset. The scholarly literature on policymaking recognizes the importance of the network conceptualization of the policy process [5,15,23]. As Sandström and Carlsson (p. 505) [24] aptly summarize, "the web of interactions within policy producing structures is an important aspect to consider when explaining policy outcomes".

We construct a network using citations to the scientific literature by US federal regulatory agencies' public justifications of regulations. All major regulations since 1981 are required, through a series of Executive Orders, to be accompanied by Regulatory Impact Analyses (RIAs), which must stipulate the problem to be addressed, the proposed rule's anticipated benefits and costs, the relevant alternative approaches, and other factors. Among other criteria, EO 12866 [1] states, "Each agency shall base its decisions on the best reasonably obtainable scientific, technical, economic, and other information concerning the need for, and consequences of, the intended regulation". Data on agency citations to the scientific literature in RIAs allow us to track the use of science across agencies and across policy areas, including the environment, health, transportation, defense, labor, and more. In the current article, we investigate where policy-relevant research finds support. We ask two related questions. First, what are the sources of support for research that is cited most heavily by RIAs? Second, what are the sources of support for the research that is used most broadly in RIAs (i.e., across policy domains and agencies)?

The data include citations to scientific literature from 104 Regulatory Impact Analyses completed between 2008–2012.[1] For the purpose of this study, "scientific literature" is defined to be an article found in the Web of Science citation index supported by Thompson Reuters, a definition that is commonly employed in the bibliometric literature [7,11,13,25]. These include regulations from a wide range of agencies and, therefore, disparate substantive policy areas. In addition to collecting and coding scientific citations for each RIA, we use the Web of Science [14] to collect citation attributes of the cited research, which include the authors' affiliation(s), and the sources of financial support acknowledged in the articles.

[1] This timeline is admittedly limited, and presents an opportunity for future research to extend the data to assess changes in the patterns we observe.

2 Network Description and Exploration

The complete policy-science network we construct is visualized in Fig. 1. The network includes 104 RIAs and 823 scientific articles. As can be seen, EPA is the most regular user of scientific research. There is little cross-agency and even cross-RIA overlap in the science that is used, outside of EPA. In what follows, we study the support of the research represented in this network, identifying the funders and affiliations behind the bulk of the research, and pay particular attention to the supporters of research that span multiple RIAs. In Fig. 2 we present the list of the most prominent funders and author affiliations associated with articles cited. In terms of affiliations, we see a list of several elite universities including Harvard, Yale, Cornell, Columbia and Duke, as well as the most research-active government agency, the Environmental Protection Agency, and Canada's large government agency responsible for public health policy: Health Canada. In terms of funders, we see a list of the prominent governmental research sponsors in the US, Canada, Europe and California, including the National Science Foundation, the National Institutes of Health, EPA, the National Science and Engineering Research Council of Canada, and the European Commission. These results are largely unsurprising: the supporters of research that are associated with the large volume of scientific publications cited in RIAs include elite research universities and the largest funders of research on the planet. However, analyzing just the volume of citations leaves out an important component of the impact story: the diversity of policy that is informed by scientific research. Seen from the perspective of the supporter of the research, the return on investment in terms of policy impact depends heavily on the breadth of policy areas influenced by individual articles.

In order to assess the diversity of policy in which the research supported by a given affiliation or sponsor is used, we use methods that have been heavily adopted in bibliometric network analysis to measure the interdisciplinarity of research, with RIAs forming the disciplinary landscape. If a scientific publication has interdisciplinary impact, we expect to see it cited in RIAs that do not otherwise cite similar bodies of literature. This constitutes an analysis of the breadth of the impact of the research supported by the funders and affiliations in our data. Breadth is particularly important in this network, as most of the network is composed of largely separate components that are not connected to each other via citations. Indeed, 671 of the 823 scientific papers are cited by just one RIA. The network analytic measure, betweenness centrality, is used to assess the degree to which an article spans diverse RIAs. The betweenness centrality of a node in a network is the number of shortest paths between other nodes on which the node sits, adjusted for alternative shortest paths. Betweenness centrality measurement represents the state-of-the-art approach to assessing interdisciplinarity in scientific citation networks [4, 20–22, 26]. In the current application, we assess the betweenness centrality of an article by the number of shortest paths between RIAs on which it sits.

In Fig. 3 we present the top affiliations and funders in terms of the average number of shortest paths between RIAs on which supported articles sit.

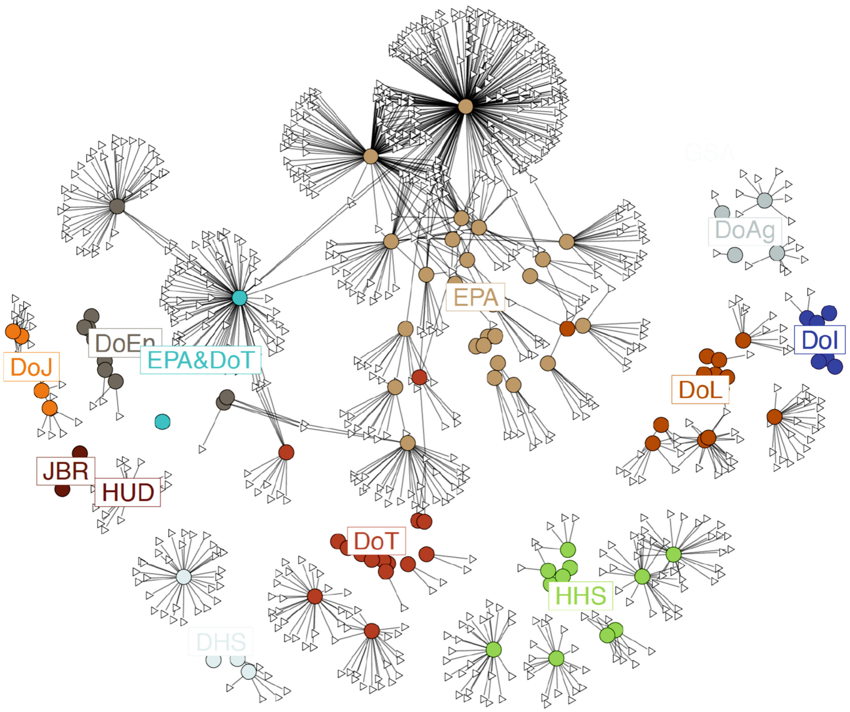

Fig. 1. Network of Regulatory Impact Analyses connected by agencies. Triangles are scientific publications. RIAs produced by the same agency are color-coordinated. Lines indicate the article is cited in the RIA.

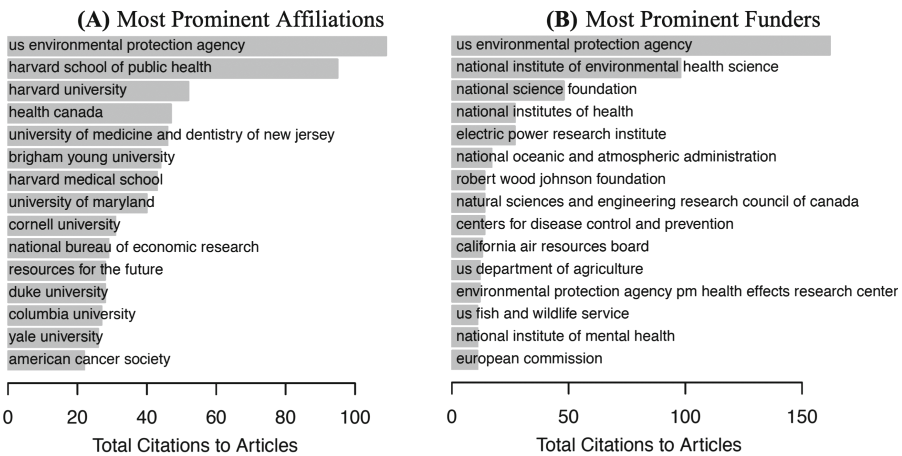

Fig. 2. Affiliations of authors of cited articles and sponsors acknowledged in cited articles are depicted. x-axis gives the number of articles in which the affiliation or sponsor appears.

These are the supporters of research whose cited articles exhibit the broadest impact in the network of RIAs and scientific publications. These lists are substantially different from the lists of affiliations and funders that support the most heavily cited articles. Notable among affiliations is the dearth of universities. Among funders, there are many fewer US federal government sources of support. These results suggest that the studies with the broadest impact on regulatory policy are conducted by researchers who are not affiliated with universities and are funded by non-US-government sponsors.

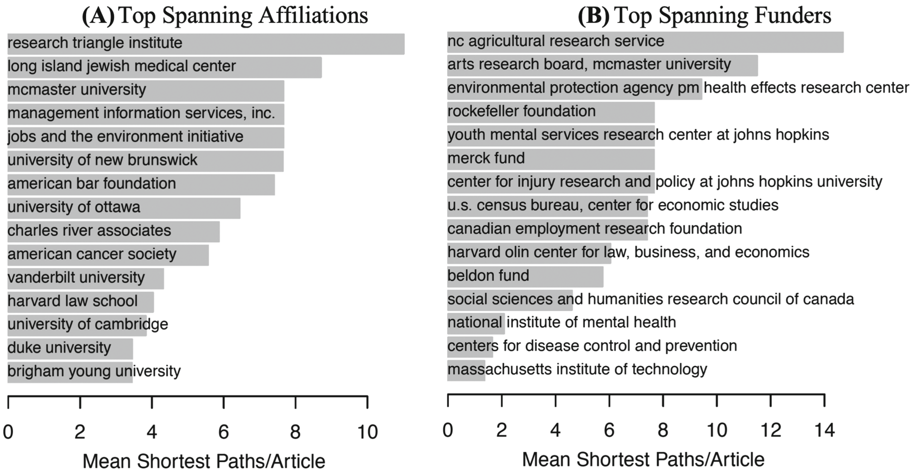

Fig. 3. Affiliations of authors of cited articles and sponsors acknowledged in cited articles are depicted. x-axis gives the weighted average number of shortest pathways between RIAs of which supported articles are part.

3 Formal Tests for Reach in the Science-Policy Network

We conduct formal tests of the hypotheses that are suggested by our analysis of the top supporters of broadly used research. We do this through the use of a hypothesis testing method referred to as a conditional uniform graph test (CUG test) [2]. In a CUG test, networks are simulated that control for structural features of the observed network, in order to test whether a feature of interest is statistically unusual given the other features that are being controlled. It is common in the analysis of betweenness to control for the number of connections to and/or from a node, as more connected nodes will tend to sit on more shortest paths due simply to their prominence. The concept of a potential boundary spanner has been used to identify nodes that have high betweenness centrality relative to degree centrality [12,16,17]. As Bigrigg et al. [6] (p. 5) note, boundary spanning potential assesses, "how likely is it if the node is removed that the network has a greater chance of being partitioned into major subnetworks."

Using this concept and measure, we test whether the articles that hold together the different parts of the regulatory policy network are less likely to be supported by US government funders and authored by scientists affiliated with universities. In the CUG tests presented in Fig. 4, we simulate comparison sets of networks that are randomly re-wired, but we hold fixed the number of articles cited by each RIA and the number of RIAs citing each article.

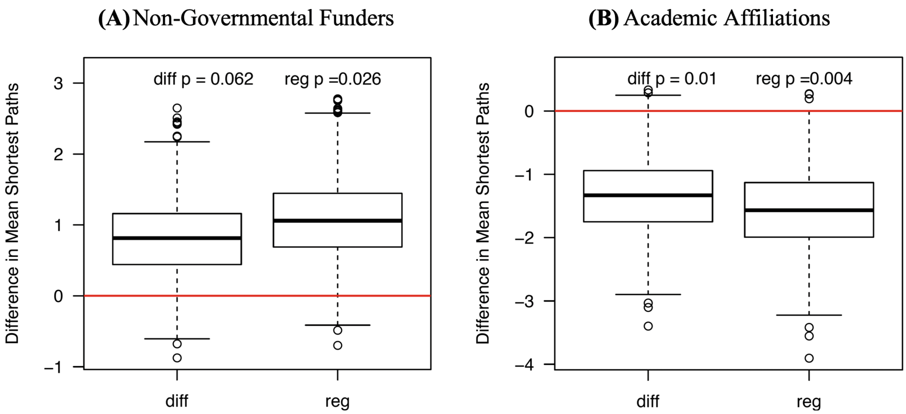

Fig. 4. Boxplots depict the distributions of differences between the average betweenness centrality of articles supported by the respective category—(A) non-governmental funders, (B) Academically affiliated authors—in the observed network and the average betweenness centrality in the respective group in the simulated networks. 1,000 simulated differences are depicted. The p-values reported are 2 times the lesser of the proportion of differences greater than zero and the proportion of differences less than zero.

The results in Fig. 4 give the differences in the average shortest paths on which articles sit, for articles supported by non-governmental and US federal government funders (A) and articles authored by those with academic affiliations and those without (B). Each plot contains two boxes. The first box “diff” reflects univariate results, calculating the difference between the articles with and without the respective feature (i.e., academic affiliation, government funding). The second box “reg” reflects multiple regression results in which the effect of the focal feature is calculated, controlling for the other feature, in a linear regression model. The hypothesis testing results confirm what we found in the descriptive analysis. Research supported by non-governmental funders sits, on average, on one more shortest path between RIAs than research that is supported by a US Federal government funder. Research that is authored by those with academic affiliations sits on 1–2 fewer shortest paths than research authored by those with non-academic affiliations.

4 Conclusion

Our results offer several important implications regarding the sources of support for policy-relevant science. First, our results demonstrate the importance to policymaking of non-university organizations that pursue basic research, such as the Research Triangle Institute. Future science of science research should investigate what it is about the selection of projects and/or the communication of results, that leads to research conducted by non-university affiliates to be more broadly used in policymaking. The second major result is that research supported by the top US government funders is less broadly influential than research supported by other funders. Future research should consider whether features of the funding process at large sponsors such as NSF or NIH steer the focus of the awards away from basic research with relevance to public policymaking.

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