National Bureau of Economic Research: Innovation Policy Postdoctoral Research Proposal

Project Summary

If scientific knowledge and innovation are crucial sources for economic growth and competitiveness, then we should want to identify and advocate those institutions and reward structures that are most efficient at bolstering this activity. The R&D enterprise, however, continues to expand, involving numerous actors and organizations (Stephan, 2012), complicating its analysis for scholars. As Jaffe and Jones (2014) highlight, the frontier for science and innovation systems is dynamic and multifaceted. Moreover, it is projected to continue to evolve in the coming decades. More research is needed not only to understand institutional norms, collaborations, and the nature of knowledge production, but also to inform policy that promotes optimal research.

In an effort to contribute to this broad discussion and to push research in a direction that is responsive to the changing scientific frontier, I propose two research projects as part of the NBER innovation policy postdoctoral fellowship. A broad literature on complements and substitutes hinges on the issue of additionality, notably the extent to which federal funding stimulates R&D production and crowds in or crowds out industry activity (e.g. Blume-Kohout et al., 2009; David et al., 2000; Diamond, 1999; Payne, 2001). This line of literature overlooks the fact that R&D support stems from a broader range of sources that include state & local and nonprofit R&D investments. For the first project, I intend to build upon the discussion of additionality by considering these sources of external support for university R&D. Not only are their proportional levels of investment increasing, this research has notable implications for innovation policy by offering a clearer understanding regarding the relationship between the myriad sources of external R&D support.

For the second project, I intend to examine innovation policy from a slightly different perspective – R&D investments in emerging scholars. There is a large literature that traces the activity of STAR scientists in terms of their patterns of invention and innovation. This research has predominantly focused on the scientific and knowledge production of senior, established scientists (e.g. Zucker & Darby, 1996), yet it overlooks the professional trajectory and antecedent factors that led these eminent scholars to this position. To gain a stronger understanding of the department-level organizational factors and innovation policies that place emerging scientists on a track for a successful career, I intend to examine R&D investments in scholars at an earlier point in their career – in graduate school. In doing so, I will draw upon data from the National Science Foundation's prestigious Graduate Research Fellowship Program. With access to complete data on awardees and honorable mentions and their respective institutions and departments, I plan to build a database that traces a sample of these individuals over time to examine how R&D investments in emerging scholars affect their research trajectories. Moreover, data on the set of honorable mentions provides a unique opportunity to construct a control group of individuals with comparable research capabilities at the baseline.

Both of these projects address issues related to innovation policy that deserve more attention. For the first project, too often we conflate external support for R&D with federal funding when in fact many more players are involved in the R&D process. Greater attention is needed to clarify the roles and relationships of these external organizations. As for the latter, with too much attention on senior scholars, there is not enough understanding regarding the antecedent factors that place these

individuals on a successful professional trajectory. This project aims to shift the focus upstream within an individual's career to examine department-level organizational factors and innovation policies among emerging scholars. Each of these projects is currently at various stages of progress with the former being more developed. The second project will require additional preliminary work to build the database; nevertheless, I am very excited about its potential. To demonstrate my progress with the first project, I have provided additional detail regarding the motivation and research design.

R&D Funding – Complements vs. Substitutes

A broad literature on complements and substitutes hinges on the issue of additionality (e.g. David et al., 2000). Evidence of substitution would suggest that certain actions would deter from investment or research that otherwise would have been practiced, while evidence of complements would stimulate additional R&D activity by serving as a signal of quality and future demands. Much of the attention on the nature of additionality for various sources of R&D support, however, focuses broadly on the relationship between federal and industry funding. This line of scholarship overlooks the expanding number of institutions directing support to R&D. This research project looks beyond these two broad terms and considers the role of state & local and nonprofit R&D investments as well.

In doing so, this project examines R&D activity within academic institutions. Data from the National Science Foundation indicate that state and local governments and nonprofit organizations each provided between 5.5 and 6.5% of all R&D funding from 2010 – 2012; slightly more than industry (Table 1). This is not surprising as research is finding that state governments are directing greater attention toward university R&D to bolster economic activity (Feldman et al., 2013). Meanwhile, nonprofit funding of academic research has been increasing as charities fill in gaps from decreases in federal and industry budgets, often in the bio-medical fields to increase research on treatments for diseases (Feldman & Graddy-Reed, 2013). As universities continue to diversify their portfolio of external support, it is essential to consider the relationship between these various sources of funding.

Table 1: University R&D expenditures by funding source

Year	All R&D^	Federal	State/Local	Industry	Internal	Nonprofit	Other
2010	61,257	61.18%	6.29%	5.22%	19.49%	6.11%	1.71%
2011	65,274	62.46%	5.87%	4.87%	19.30%	5.90%	1.59%
2012	65,775	61.01%	5.63%	4.99%	20.79%	6.13%	1.45%

^Values in millions of current US dollars

Source: National Science Foundation, National Center for Science and Engineering Statistics, Higher Education Research and Development Survey; NSF 14-303 Table 1

To assess the relationship between federal R&D investments in university activity with a series of other external sources of R&D support, I plan to apply an empirical approach to this question that has not been used in this line of scholarship. Applying appropriate econometric techniques to disentangle the causal pathway has been an added challenge to this line of research. As David, Hall and Toole (2000) emphasize in their literature review, simultaneity serves as a central design threat. Notably, I plan to use the lagged dependent variable to instrument for the university's capacity to secure external non-federal funding and include department-level fixed effects to control

for time-invariant factors that may affect the institution's ability to secure funding. This approach conditions on both the fixed effects and the lagged dependent variable. Equation 1 draws from Arellano and Bond's seminal work (1991) and presents the two-stage model for the outcome External R&D – specifically, state & local government R&D and nonprofit R&D, respectively – instrumenting the lagged dependent variable two periods.

$$External\ R\&D_{it} = \alpha_i + \beta_1 Federal\ R\&D_{it} + \beta_2 External\ R\&D_{it-2} + \beta_k X_k + \varepsilon_{it} \quad (1)$$

To assess the validity of this approach I plan to apply this empirical technique using industry R&D as the dependent variable. Given that considerable scholastic attention has been placed on this relationship, I plan to compare these results to other studies that employed alternative econometric methods (Blume-Kohout et al. 2009; Payne, 2001).

This project uses department-level data from the National Science Foundation Survey of Research and Development Expenditures at Universities and Colleges/Higher Education Research and Development Survey. I intend to restrict the sample of universities to all U.S. doctoral-granting academic institutions with a research component, as defined by the Carnegie Classification. While selection bias has been of concern for studies that focus on firm-level R&D investment activity (David et al., 2000), this does not pose a concern for this analysis given that I am looking at the population of U.S. research institutions. Data on R&D investment is stratified by source, ranging from federal, state & local government, industry, institutionally financed and other, a proxy for nonprofit funding.

I plan to look at academic R&D investment activity from 2010 – 2013. Until 2010, nonprofit funding was reported in the category of 'other', which also includes international government contributions. But due to its significant contribution, the National Science Foundation began to separate out nonprofit funding and report it as its own source of funding. Now separated for fiscal years 2010 – 2013, nonprofits accounted for 78 – 81% of what would have been reported as 'other' in previous years. Pulling nonprofit contributions out has left the remaining 'other' as 1.45 – 1.71% of all academic R&D expenditures. These values are consistent when looking at R&D for the science and engineering fields as well. Using this approach, I will be able to estimate the relationship between federal and nonfederal external funding sources of academic R&D.

Previous research

This research builds off my dissertation, which identifies, categorizes, and critically evaluates the impact of *state* government R&D investments on small business innovation. While globalization is shifting the comparative advantage of traditional inputs of production, the input of knowledge and the agglomeration economies produced through innovative activity are spatially proximate. This places state governments in a fortuitous position to invest in innovative and entrepreneurial programs and leverage the local economic benefits. My dissertation's examination of the SBIR State Match program in relation to the federal program also offers the unique opportunity to empirically analyze the effects of marginal changes in R&D investment. This research offers a new contribution by assessing the impact of R&D investments at the research project level rather than the firm.

References

Arellano, M. & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. The Review of Economic Studies, 58(2), 277-297.

Blume-Kohout, M. E., Kumar, K. B. & Sood, N. (2009). Federal Life Sciences Funding and University R&D. National Bureau of Economic Research Working Paper Series, No. 15146.

David, P. A., Hall, B. H. & Toole, A. A. (2000). Is public R&D a complement or substitute for private R&D? A review of the econometric evidence. Research Policy, 29(4-5), 497-529.

Diamond, A. M. (1999). Does Federal Funding "Crowd In" Private Science? Contemporary Economic Policy, 17(4), 423-431.

Feldman, M.P. and Graddy-Reed, A. (2014) Accelerating Commercialization: A New Model of Strategic Foundation Funding. *Journal of Technology Transfer.* 39: 503-523.

Feldman, M.P., L. Lanahan, and I. Lendel (2014). Experiments in the Laboratories of Democracy: State Scientific Capacity Building, *Economic Development Quarterly, 28*(2), 107 - 131.

Jaffe, A. & Jones, B. (2014). The Changing Frontier: Rethinking Science and Innovation Policy. University of Chicago Press.

Muscio, A., Quaglione, D. & Vallanti, G. (2013). Does government funding complement or substitute private research funding to universities? Research Policy, 42(1), 63-75.

Payne, A. A. (2001). Measuring the Effect of Federal Research Funding on Private Donations at Research Universities: Is Federal Research Funding More than a Substitute for Private Donations? International Tax and Public Finance, 8(5), 731-751.

Payne, A. A. & Siow, A. (2003). Does Federal Research Funding Increase University Research Output? Advances in Economic Analysis & Policy, 3(1), Article 1.

Stephan, P. (2012). How economics shapes science. Cambridge, MA: Harvard University Press.

Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences*,*93*(23), 12709-12716.