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The impacts of science and technology policy interventions on university research: Evidence from the U.S. National Nanotechnology Initiative

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ABSTRACT

We examine how the National Nanotechnology Initiative (NNI), a recent U.S. government science and technology (S&T) program launched in 2000, affects the nature of university research in nanotechnology. We characterize the NNI as a policy intervention that targets the commercialization of technology and a focused research direction to promote national economic growth. As such, we expect that the NNI has brought about unintended consequences in the direction of university–industry knowledge flows and the characteristics of university research output in nanotechnology. Using a difference-in-differences analysis of U.S. nanotechnology patents filed between 1996 and 2007, we find that, after the NNI, U.S. universities have significantly increased knowledge inflows from the industry, reduced the branching-out to novel technologies, narrowed down the research scope, and become less likely to generate technological breakthroughs, as compared to other U.S. and non-U.S. research institutions. Our findings suggest that, at least in the case of the NNI, targeted government S&T programs may increase the efficiency of university research, but potentially do so at a price.

1. Introduction

Since Vannevar Bush's (1945) influential report, *Science: The Endless Frontier*, that highlighted the importance of basic research for advances in applied research and commercialization, university research has become a major vehicle through which governments seek to promote national economic growth. Based on the logic that stronger government support would enhance the effectiveness of the national innovation system, government science and technology (S&T) programs have become primary funding sources of university research in the U.S. (Nelson, 2004; Stephan, 2010). These programs are often associated with specific missions to be accomplished, as famously represented in the Apollo Program that aimed at "landing a man on the Moon."[1] In fact, over 90% of the government research and development (R&D) spending in the U.S. is considered to have mission-oriented rationales (Mowery, 2009). How might, then, targeted government S&T programs have influenced the nature of research in the U.S. universities, arguably the most significant beneficiary of such programs? This paper is our attempt to examine this question.

While national priorities play a role in setting broad research directions in Bush's manifesto, his original argument suggested a high degree of autonomy for science (Bush, 1945; Nelson, 2004; Mowery, 2009). Further, researchers have argued that decisions on specific areas to be funded should be left to scientists (Martin, 2003; Mowery, 2009). This casts a fundamental contrast with government S&T programs that promote mission-oriented initiatives, which may redirect university research to work on specific technology areas to maximize economic payoffs from the funding (Dasgupta and David, 1994). In particular, government-mandated missions such as ensuring the U.S. economic leadership may significantly affect the institutions of knowledge production and, hence, alter the landscape and flows of knowledge. It is generally understood that universities specialize in basic research (Nelson, 1959; Dasgupta and David, 1994), advance technology developments by often bringing about serendipitous exploration and technological breakthroughs (Mansfield, 1991; Nelson, 2004), and operate on a functional norm that substantive findings should be universally available to the research community (Merton, 1973). Government S&T programs with specific orientations such as commercialization can undermine these general assumptions on university research. We posit that commercialization-oriented S&T programs alter the characteristics of university research in technology development by influencing the direction of university research and by potentially overemphasizing the link to commercialization.

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[1] On May 25, 1961, addressing to a joint session of the U.S. Congress, then President John F. Kennedy stated a goal of "landing a man on the Moon and returning him safely to the Earth" by the end of the 1960s. This led to the Apollo Program, by far the largest single government S&T program in the U.S. history.

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Despite the existing research on the influence of government funding on overall research outcomes, little is known about how government initiatives with specific targets may interfere with science and technology (Jaffe, 2006). Researchers have recently begun to address this issue by investigating the role of institutions and science policy in knowledge accumulation and the direction of scientific research (Murray et al., 2009; Furman et al., 2010; Furman and Stern, 2011). Among what remains under-explored is the effect of government initiatives on knowledge flows and the nature of knowledge produced in the institutions such as universities that rely heavily on government funding. This omission is puzzling because government initiatives may be conflicting with the propositions that institutions of scientific research should be self-governed and thus independently decide the priority of their research agenda (Polanyi, 1962), and that the results of scientific research should be publicly disclosed and shared (Dasgupta and David, 1994; Nelson, 2004). To fill this void, we examine the impacts of a particular S&T program on university research in terms of the direction of knowledge flow between the university and the industry and the characteristics of research output such as branching-out to novel technologies, research scope and technological breakthroughs.

We begin by noting that, traditionally, universities have been more specialized in basic research than in applied research (Arora and Gambardella, 1994), operating on a functional norm of disinterestedness (Merton, 1973), and the institution that primarily explores to develop technological breakthroughs (Mansfield, 1991; Nelson, 2004). Building on these notions, we argue that this program's particular emphasis on commercialization will induce university research to increasingly utilize knowledge flows from industry because firms tend to have technologies to solve problems that are directly relevant to market demand; due to greater interests in economic returns, university researchers will reduce accessibility to their findings through secrecy and incomplete disclosures, which, in turn, forecloses their own possibility of branching-out to subsequent novel technologies. We also contend that a focused research direction mandated by the program will influence university research to reduce the exploration of uncertain technologies and hence the variance of technological outcomes, and thereby lead to curtailed technological breakthroughs. Our empirical setting is the National Nanotechnology Initiative (NNI), a U.S. federal government S&T program launched in 2000. Since its inception, the NNI has coordinated the disbursement of over $ 14 billion by 2011. By funneling the budget into nanotechnology R&D, the NNI guides the direction of university research toward the research agenda it has set up (Bush, 1945; Dasgupta and David, 1994; Mowery, 2009). The NNI is clearly a targeted government initiative in that it not only serves general government missions in national defense, agriculture, health and education, but also pursues its own mission of securing the economic leadership of the U.S. in nanotechnology.[2] In particular, the NNI is intended to "advance the U.S. productivity and industrial competitiveness through coordinated investments in nanotechnology."[3] Based on this mandate, we characterize the NNI as the onset of a policy intervention that emphasizes the commercialization of nanotechnology and a focused research direction to attain national economic growth. This program sets the university apart from the private sector that was largely unaffected by this policy drive. It also distinguishes the U.S. from other countries that were free of such a policy shift during the period of our study. Hence, the NNI provides a nice natural experiment that we can exploit to isolate the impact of this particular policy intervention on university research outcomes.

Analyzing 3720 nanotechnology patents filed with the United States Patent and Trademark Office (USPTO) between 1996 and 2007, we find support for our hypotheses. Specifically, our difference-in-differences estimation show that, following the NNI, U.S. universities have become (1) more reliant on industry-generated knowledge; (2) less prone to branch out to novel technology areas; (3) narrower in patent scopes; and (4) less likely to produce technological breakthroughs. These outcomes are totally counterintuitive because the goals of government S&T programs are in general to facilitate knowledge transfers from university to industry, not the reverse, and to build a strong national innovation system characterized by greater innovative output. Our findings suggest that targeted S&T policy interventions do exert significant impacts on university research, but potentially in an unexpected way.

2. NNI as a natural experiment

The NNI is the U.S. federal interagency program for coordinating R&D and enhancing communication and collaborative activities in nanoscale science, engineering and technology. The NNI represents the individual and cooperative nanotechnology-related activities of 25 federal agencies[4] with a range of research and regulatory roles and responsibilities. The primary goals of this program are to increase the transfer of new technologies from university to industry and facilitate the commercialization of nanotechnology (NNI Strategic Plan (NSTC, 2011b)). Federal agencies put coordinated efforts toward identifying specific R&D targets, setting up R&D directions[5] in nanotechnology and expediting commercialization by focusing on applications (NNI Research Direction II (NSTC, 2004)).

Funding is the main mechanism that the NNI uses to achieve its goals by supporting nanotechnology research. The participating federal agencies have pre-allocated R&D budgets for nanotechnology; the publicized NNI budget represents the collective sum of these agency-level budgets. Federal research grants are awarded by individual agencies in accordance with their respective missions. While the NNI utilizes a traditional government funding system, it drives a national strategic plan for nanotechnology with integrated and unified directions across funding agencies. The NNI has been one of the top priorities in the S&T policy agenda that former

[2] The President's Committee of Advisors on Science and Technology noted that the NNI has an "excellent multi-agency framework to ensure U.S. leadership in this emerging field that will be essential for economic and national security leadership in the first half of the next century" (NNI, *The Initiative and Its Implementation Plan*, (NSTC, 2000)).

[3] *The 21st Century Nanotechnology Research and Development Act*. Public Law 108–153. The 108th Congress.

[4] The federal agencies participating in the NNI include Consumer Product Safety Commission, Department of Defense, Department of Energy, Department of Homeland Security, Department of Justice, Department of Transportation (including the Federal Highway Administration), Environmental Protection Agency, Food and Drug Administration, Forest Service, National Aeronautics and Space Administration, National Institute for Occupational Safety and Health, National Institute of Food and Agriculture, National Institute of Standards and Technology, National Institutes of Health, National Science Foundation, Bureau of Industry and Security, Department of Education, Department of Labor (including the Occupational Safety and Health Administration), Department of State, Department of the Treasury, Director of National Intelligence, Nuclear Regulatory Commission, U.S. Geological Survey, U.S. International Trade Commission, and USPTO. Source: The National Science and Technology Council (NSTC), *Supplement to the President's FY 2012 Budget*, (NSTC, 2011a).

[5] An early-stage plan for the NNI had very specific guidelines. For instance, the deliverables in the first five years were to "...develop new standard reference materials for semiconductor, lab-on-a-chip-technologies, nanomagnetics, and calibration and quality assurance analysis for nanosystem first achieved by FY2003... [and to] develop 3D measurement methods for the analysis for physical and chemical at or near atomic spatial resolution first achieved by FY2004 ..." (NNI, *The Initiatives and Implementations Plan*, (NSTC, 2000)).