A Case for Increasing National Institutes of Health Appropriations: A policy memorandum to STEM Professors interested in federal research funding

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Executive Summary: The National Institutes of Health (NIH) serves a central role in funding scientific research in the US. The authors contend that NIH funding of basic research is a necessary pre-requisite for businesses and corporations to innovate and create new products, thus stimulating the economy. NIH funding facilitates the training of future scientists, thereby ensuring a steady stream of experts entering industry and national lab positions. While the return on investment (ROI) of NIH funding is difficult to fully quantify, the qualitative results cannot be overemphasized. Scientists must stress secondary and tertiary effects of NIH funding to the general public and to legislators, to ensure continued scientific and societal progress.

I. Introduction

Congressional appropriations for federal funding agencies, especially the NIH, are the subject of continual debate. Presidential administrations implement agency mandates in drastically different ways; however, the power of the purse eventually rests with Congress. This was most recently demonstrated in 2017, when Congress approved its highest level of NIH funding, well over that requested by the Trump Administration (Staff 2017). As Congress debates its appropriations for agencies like NIH, it is influenced by diverse interest groups with distinct agendas that may or may not coincide with increased NIH appropriations (Grossman and Helpman 2000). Opponents of increased federal investment in scientific research cite three main reasons for their views: 1) federally funded research and development (R&D) focuses on producing ideas, which have no intrinsic economic value, 2) the value of basic research is difficult to quantify because it stems from follow-on innovation, which may occur years later in a way that is not obviously linked with the enabling science, and 3) some R&D sectors could, in theory, be better funded through private investment. This policy memo counters these claims by analyzing current metrics to measure the impact of federal research expenditures. We demonstrate that federally funded scientific research forms a core part of scientific and economic advancement in the US and substantially enhances the impact of private investment.

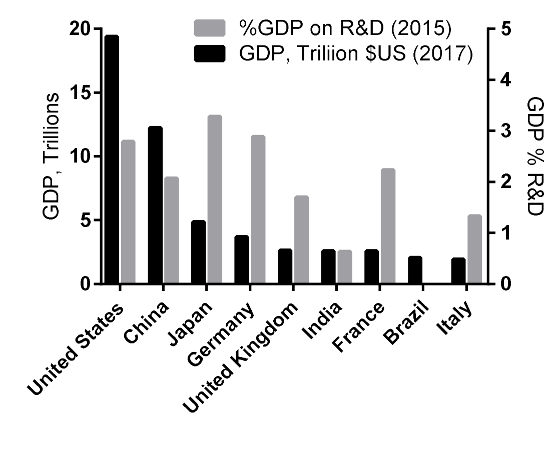

Figure 1. Top National GDP and %GDP R&D Spending. GDP in trillions shown in black on left axis and **%** GDP spent on R&D shown in gray on

The US spends the largest % GDP on R&D of any other country, besides Japan and Germany (Figure 1). The US and China lead the world in the number of scientific publications by a large margin; however, China files nearly 5 times the number of patents as the US, at a lower percent GDP (Figure 2) (T. W. Bank n.d.). If one compares Figure 1 and Figure 2, those countries with the highest GDP also generally have the largest number of patents accepted. However, the impact of a country's level of patent procurement is difficult to translate into economic health. For instance, advances in scientific

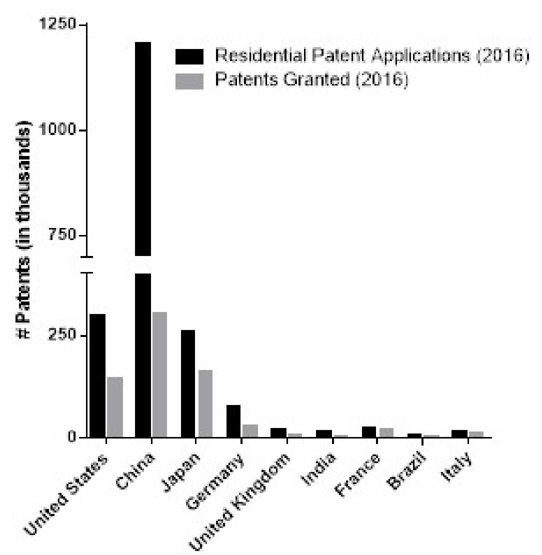

Figure 2. Patent Applications Filed by Top 10 GDP Countries Worldwide. Number of patents applications filed and granted in thousands per country.

knowledge easily cross borders and as a result, US R&D spending generates economic returns globally rather than solely within the US. A further complication is that ROI's are based on the reduction of an idea to practice in the form of a scientific publication, patent, or other definable measure. Unfortunately, ROI's for NIH funding do not take into account the production of sound scientific principles that are utilized for private commercial scientific advancement. For example, the aerospace and rocket science fundamentals that Elon Musk relies upon free of charge when he sets out to innovate in the private space industry arose from academic endeavor. Furthermore, drastic changes to R&D investment through the political process can further complicate analysis of ROI from NIH funding.

II. Historical and contemporary trends in NIH public funding

Historically, the NIH has followed the lead of the National Science Foundation (NSF) and its predecessor the Office of Scientific Research and Development (OSRD), funding mostly basic science, defined as science that may not result in immediate obvious commercial potential. The argument for federal investment in basic science for its own sake was articulated most notably by Vannevar Bush in 1945, then chair of the OSRD. Bush's article, "Science-The Endless Frontier" (Bush 1945), served as a blueprint for establishing the NIH and other basic science funding agencies after WWII. Bush called for the federal government to focus on basic rather than applied science. However, this blueprint was instilled with some expectation that the ideas and information generated from basic research would naturally translate into improvements in the economy, the quality of life, and the security of the nation.

Apart from the Department of Defense, the NIH has one of the largest budgets of all federal science funding agencies, with a budget over twice as large as those of the Department of Energy, the National Science Foundation, the National Aeronautics and Space Administration, and the Department of Agriculture (Cook-Deegan 2015). In 2016, NIH provided approximately $24.6 billion in research funding for scientists in all 50 states as well as the District of Columbia and US territories (W. Bank n.d.). When adjusted for inflation however, the NIH budget peaked in 2003, with funding for 2019 at 9% less than 2003 funding (Johnson and Sekar 2018).

III. Measuring NIH's ROI

What is the optimum NIH funding level? One way to answer this question is to compare the return on investment (ROI) that NIH generates in terms of practical benefits to the public (Freeman and Reenen 2009), with ROIs generated by spending in other ways or returning the funds to the public in the form of reduced taxes. NIH's emphasis on basic research makes it difficult to measure ROI, because the return is often indirect and accrued only after many years. However, private industry benefits from building upon a foundation of well tested theories and laws established by basic science. Additionally, the training provided by NIH is what generates the trained ranks of employees of these same commercial firms. We offer a background on defining ROI for this sector as well as specific examples to address the issues of: 1) knowledge spillover, 2) accelerated technological development, and 3) accounting for market failures.

Measures of ROI on NIH funding based on total number of papers or patents published can be misleading, as a relatively select few papers and patents are highly read and cited. Additionally, citations for patents are often only utilized for a different purpose than for scientific publications, instead used as a mechanism for establishing prior art (inventorship date) rather than developing a particular field of research. As the general goal for researchers receiving NIH funding is to publish high quality research, there here have been many attempts to quantify the "impact factor" of a publication or set of publications based on such metrics as citation rates (Hutchins et al. 2016). However, these metrics are problematic because different types of publications receive different levels of interest. For example, a review article summarizing recent progress in a given biological discipline may garner thousands of citations while offering no novel information (Klionsky et al. 2016). Alternatively, someone may generate novel information using that same review article. As a result, NIH has begun deemphasizing citation-based impact factors as measures of the value of research (Triaridis and Kyrgidis 2010).

Arguably, a more important rubric from a policy standpoint is quantifying NIH's impact on job creation and economic growth, allowing legislators to justify their support of NIH funding to their constituencies. The NIH estimates that every $1 of NIH health research funding returns $2.21 in goods and services in just one year and, in addition, every NIH R01 Grant (traditional funding instrument of NIH for tenure track professors in life sciences) creates an average of seven high quality jobs (Center 2012). In 2016, NIH funding supported 380,000 jobs and created 27,000 new jobs (Research 2017). Importantly, jobs generated through NIH funding are created at research institutions embedded in local communities. Those institutions committed to improving efforts to secure NIH funding can be readily championed by local politicians as progenitors of "new jobs" with definite life spans at least as long as the grants they derive from.

Another benefit of NIH-funded research is that it directly promotes the sharing of knowledge as opposed to the generation of trade secrets. NIH funding is built on the principle of "publish or perish," meaning that laboratories with above average publication records have higher probabilities of receiving NIH funding. NIH measures of productivity based on publication record extend to institutions as a whole, such that there are direct incentives for research institutions as a whole to be productive in their use of NIH funding. As an alternative to measurements of productivity using citations or publications, the NIH could consider analogous forms of productivity, such as patent procurement, with greater weight to further incentivize knowledge dissemination and increased awareness of the patent system.

IV. Specific Examples of NIH Funding and Economic Impact

To convince legislators of the value of NIH funding, it is helpful to cite specific past examples of how NIH funding has resulted in measurable public benefits. One of the benefits cited should be knowledge spillover, or the utilization of novel knowledge in areas not intended to be direct beneficiaries of such research. For example, NIH funding for the Human Genome project (HGP), which decoded the human genome through the use of shotgun sequencing methods developed by Craig Venter (Hood and

Rowen 2013), not only increased our understanding of human health and medicine, but resulted in spillover benefits for follow-on innovation in areas such as agriculture, industrial biotechnology, environmental protection, and national security (Toole 2012). This technology has led to the sequencing of nearly every living organism on the planet, elucidating evolutionary trees connecting all organisms past and present, and leading to innovation in the biotech industry allowing for the development of new targets, more sophisticated treatments involving personalized medicine, and genetic engineering. The $3.8 billion federal investment in the NIH-funded HGP has led to an estimated $1 trillion in economic growth from 1988-2013, corresponding to a ROI of 263 to 1. It is estimated that the project has generated more than 4.3 million job-years of employment.

Another specific example of ROI for federal research spending is accelerated drug development. The creation of innovative new drugs by pharmaceuticals is often enabled by earlier, federally funded research (Cockburn and Henderson 2013). One study indicated high ROI in this area due to cooperation between publicly funded academic labs and the private sector bridging drug discovery and development (Toole 2012). This occurs as NIH funding incentivizes the discovery of drug targets (basic research) that pharmaceutical companies utilize to develop molecules for treatment (applied research) (Thielking 2019). Further clarifying incentive structures between these academic labs and pharmaceutical companies, taking into account their different self-interests, could also result in more efficient use of NIH resources. NIH funding is an accelerator of knowledge utilized directly by industry, and as such, it is important to consider indirect benefits such as the discovery of targets for pharmaceutical treatment when calculating ROI.

Finally, federal research programs take the place of otherwise unprofitable industries, benefiting society simply by correcting market failures. Benefits of this nature can be quantified through decreases in mortality and morbidity due to new vaccine development. In addition to saving lives, the national vaccination program has an economic benefit. For children born in 2009 alone, the US immunization program prevented diseases that would have incurred $1.8 billion in direct treatment costs (Murphy and Topel 2006). In contrast, Novartis recently proposed a one-time gene therapy treatment for spinal muscular atrophy (SMA) that would cost a patient with this disease nearly $2.1 million (Miller and Humer 2019). The development of this treatment most likely stemmed from the HGP. As increased federal expenditure fuels basic research, new patent-eligible cures could be developed for SMA that bring down the cost to the public, whereas with the knowledge currently available, there is little incentive for pharmaceutical companies to develop a competing treatment.

V. Conclusion

Polemics about economic waste and a burgeoning bureaucracy in the Federal government are prevalent during political campaigns. Many Americans strongly support decreases in federal spending (or at least decreases in federal taxation), even if it means reductions in outlays for scientific research. News stories about new treatments for a given disease are often illustrated by their impact on specific patients and significantly oversimplify their discovery. Regrettably, these stories often do not articulate the key role that federal funding played in making the discovery possible or in allowing the discovery to progress into commercial development. Americans believe in the ability of science to conquer diseases, but they generally have a low awareness of how such discoveries are made or how governments incentivize researchers to make them. Often times, both in court and in the court of public opinion, experts guide the public knowledge on a given scientific subject. However, though the scientific researcher may understand the funding environment, they might have difficulty translating to the public how an increased budget leads to public benefit. Therefore, we have analyzed possible ways to measure economic benefit and long-term impact from NIH funding as a means of increasing awareness of this issue for scientists interested in public policy.

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