Patents as proxies: NIH hubs of innovation

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The rate of invention may be a valuable metric for identifying strategic R&D investments to enhance knowledge creation, translational value and economic potential from NIH-supported research.

The medical innovation sector of the US economy employs approximately one-million US citizens, generates $84 billion in wages and salaries, and exports $90 billion in goods and services[1]. Although the central mission of the National Institutes of Health (NIH) is to improve human health through medical research and discovery, legislators on both sides of the political aisle often point to the NIH as an engine for innovation-based economic growth.

Evidence shows that federally funded R&D is an economically productive use of taxpayer dollars. The US academic research system spurred the formation of 1.7 new companies per day and created 657 new products in 2010 alone[2]. It has been estimated that approximately 30% of the total value of the NASDAQ has roots in academic research[3]. More specifically, a 2008 study concluded that every $1 spent on NIH research results in $2.21 in local economic impact[4]. Overall, these dollars contribute to direct employment, indirect employment, increases to the tax base, new businesses and increases to gross domestic product[5].

Seeking to further leverage the economic power of federally sponsored R&D, the Office of Management and Budget (OMB) and the Office of Science and Technology Policy (OSTP) have requested that federal agencies tailor their budgets to "give priority to R&D investments that have the potential to foster biological innovations"[6]. The Obama administration also unveiled the first National Bioeconomy Blueprint in 2012, which included a menu of policy options designed to optimize economic growth from federal R&D[7]. Not surprisingly, the highest priority for agency leaders was to identify strategic R&D investments to enhance economic growth. Voices in the scientific community have also advised policymakers to adopt a more surgical approach to research budgeting, eschewing blunt, agency-wide increases and focusing additional resources more strategically[8].

But how will agency leaders know where to invest more strategically, and where will they find the economic evidence on which to base such decisions? One metric that could serve as a proxy for knowledge creation, translational value and economic potential from NIH-supported research is the rate of invention, as represented by the volume of new patents resulting from funded research. Patent activity correlates positively with regional economic health, as high rates of patent creation are geographically associated with higher than average wages, lower regional unemployment and more startup company activity[9].

However, a simple patent count is an imperfect and noisy proxy for economic impact, because patents vary in their impact and commercial potential. A widely accepted approach for assessing the impact of patents is the forward citation count. Forward citations are references to a particular patent by later patent filings and are useful for identifying whether a particular patent was integral to subsequent technological development in a field. Multiple forward patent citations are indicators of impact in the private sector; each incremental patent citation represents millions of dollars of additional private sector R&D, while substantially increasing the market value of a controlling company[10–13]. Taken together, patent counts and forward citation rates can highlight those areas of federal R&D most likely to contribute to future development and economic activity, making them a potentially key metric for policymakers.

The public website of the NIH, *NIH RePORTER*[14], provides access to project-specific patent information that has been systematically collected from recipients of federal grants, as required by the Bayh-Dole Act[15]. To date, these data have received little external analysis and commentary in the context of research portfolio analysis, particularly by leaders of federal agencies and policymakers. This seems surprising given the objective significance of inventions as a dimension for assessing the return on investment for funded research. Like other metrics that require self-reporting by grant and contract recipients, these data may not be entirely complete. Nevertheless, this publicly available information on patents resulting from NIH-supported research provides a rich basis for exploring many intriguing questions.

From the 21 primary grant-making institutes and centers at NIH[16], 6,659 unique patents were approved by the US Patent and Trademark Office (USPTO) from 2003 to 2012. Overall, NIH-funded external research yields about 2.5 new patents for every $100 million of external grant and contract funding. With approximately $4 billion available each year for new and competing awards, NIH can expect each year's new awards to generate at least 100–120 new inventions. Since a material amount of the NIH budget is allocated towards clinical research and training awards—two areas that are mission-oriented but would not be expected to generate new patents—this figure is likely to be significantly higher when looking at purely basic or applied research programs.

To look at patent quality by forward citations, we surveyed 50 randomly selected, unique patents from each of 21 institutes, going back to 1980. We then cross-referenced these data with forward citation records available from the USPTO. We found an overall forward citation rate for all NIH patents of 7.9. This is more than twice the rate (3.1) reported for private sector patents in the United States[10] and six times the rate (1.3) reported in a study of forward citation rates for European biotech sector patents[17], and is evidence that NIH-supported research is

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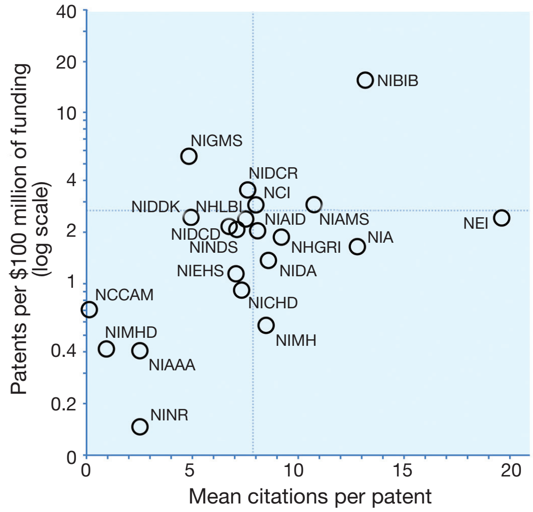

Figure 1 Patent quantity and quality. Means are shown with dotted lines. NCCAM, National Center for Complementary and Alternative Medicine; NCI, National Cancer Institute; NEI, National Eye Institute; NHGRI, National Human Genome Research Institute; NHLBI, National Heart, Lung, and Blood Institute; NIA, National Institute on Aging; NIAAA, National Institute on Alcohol Abuse and Alcoholism; NIAID, National Institute of Allergy and Infectious Diseases; NIAMS, National Institute of Arthritis and Musculoskeletal and Skin Diseases; NIBIB, National Institute of Biomedical Imaging and Bioengineering; NICHD, National Institute of Child Health and Human Development; NIDA, National Institute on Drug Abuse; NIDCD, National Institute on Deafness and Other Communication Disorders; NIDCR, National Institute of Dental and Craniofacial Research; NIDDK, National Institute of Diabetes and Digestive and Kidney Diseases; NIEHS, National Institute on Environmental Health Sciences; NIGMS,National Institute of General Medical Sciences; NIMH, National Institute of Mental Health; NIMHD, National Institute on Minority Health and Health Disparities; NINDS, National Institute on Neurological Disorders and Stroke; NINR, National Institute of Nursing Research.

effective in generating transformational results with substantial potential for economic impact.

The horizontal dotted line of **Figure 1** shows the mean volume of unique patents reported per $100 million invested in extramural research by the 21 NIH institutes between 2003 and 2012. The vertical dotted line shows the mean number of citations per patent. There is little correlation between total budget size and patent activity as, for instance, the National Institute of Dental and Craniofacial Research (NIDCR) has one of the smallest budgets, yet the third-highest rate of patentable inventions. The National Institute of Biomedical Imaging and Bioengineering (NIBIB)-funded research is notable for high performance with respect to both quantity (number of patents per amount funding) and quality (citations per patent) metrics of reported patents.

Conclusions

Ultimately, the return on investment for NIH research should be measured in terms of extended human life expectancy, reduced burden of disease and long-term economic impact. Unfortunately, the latency of these outcomes makes them challenging to use as criteria for guiding current investments in research. In the short term, if policymakers wish to optimize the NIH budget for economic impact, publicly available patent outcome data compiled by the NIH should be evaluated as useful proxies for more immediate translational potential and economic impact.

The raw results presented here make it difficult to draw any conclusions at this point. However, the strong stratification among areas of science—as well as the presence of outliers—indicate that patent metrics may be worthy of additional study. For example, for larger institutes such as the National Cancer Institute (NCI) and the National Heart, Lung, and Blood Institute (NHLBI) that fall near the mean for both quality and quantity metrics, a further breakdown by study section or grant mechanism would be highly useful for determining if there are targeted awards or team structures that lend themselves to the development of new intellectual property. Conversely, these metrics must be used carefully so as not to 'punish' those in the budget process that mainly investigate important clinical questions that do not lend themselves to private sector development.

If the science policy community is successful at developing meaningful patent output metrics across NIH, policymakers and Congress may wish to supplement traditional prioritization methods with an econometric framework that identifies particular areas of science that generate endogenous economic growth, especially in times of fiscal austerity. In addition, patent data should inform efforts to meet the articulated requests of OMB and OSTP that agencies use "meaningful, measurable, quantitative metrics where possible to evaluate" the economic impact of targeted R&D investments[6].

COMPETING FINANCIAL INTERESTS

The authors declare no competing financial interests.

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