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Estimating Long-term Economic Returns of NIH Funding on Output in the Biosciences

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Advances in biomedical research have spurred dramatic improvements in both human and economic health. Between 1950 and 2009, life expectancy in the United States has increased 10 years,[1] and since 1970, this increase in longevity has produced a net national gain of $61 trillion in social value, defined as the value of a lifetime expected utility.[2] All this can be traced back to innovations in research, discovery, diagnostics, and therapies—and strong federal policy positions that have pushed the U.S. to the forefront of biomedical R&D.[3] An estimated 40 percent of U.S. medical research is federally funded.[4]

The benefit from every dollar invested by National Institutes of Health (NIH) outweighs the cost by many times. When we consider the economic benefits realized as a result of decrease in mortality and morbidity of all other diseases, the direct and indirect effects (such as increases in work-related productivity) are phenomenal.

NIH funding has also played a major role in boosting economic growth and contributing to the growth of bioscience clusters, geographic concentrations of related (competing and/or collaborating) industries or firms, with a common need for talent, technology, and infrastructure. An initial round of NIH funding encourages the hiring of more scientists and engineers, which subsequently boosts output in the bioscience industry. As production increases, private companies absorb necessary information and invest more in R&D, which further boosts the economy. The effect is a ripple, leading to growth of the bioscience clusters that attract supporting industries, such as health care, and their own allied industries. Eventually the effect translates into higher economic activity for the region. It may take years to realize the actual long-term effect of NIH funding on the economy.

Previous Milken Institute studies demonstrated that NIH funding has been a critical component in the emergence and long-term prosperity of bioscience clusters in metropolitan areas across

1. “Health, United States,” Centers for Disease Control, 2011, http://www.cdc.gov/nchs/data/hus/hus11.pdf#022 (accessed August 22, 2012).
2. Kevin M. Murphy and Robert H. Topel, “The Value of Health and Longevity,” *Journal of Political Economy* 114, no. 51 (2006), p. 897.
3. Ross C. DeVol, Armen Bedroussian, and Benjamin Yeo, “The Global Biomedical Industry: Preserving U.S. Leadership,” Milken Institute, September 2011.
4. Murphy and Topel, “The Value of Health and Longevity” p. 873.

California and in the greater Boston and Philadelphia regions. This paper establishes the long-term relationship between NIH funding and the size of the bioscience industry at the state level, using an econometric model (production function).[5]

Preliminary results show that $1.00 in NIH funding can generate at least $1.70 of output in the bioscience industry. The long-term effects may be as high as $3.20 for every $1.00 spent, depending on the model specification. These models explain over 92 percent in the overall variation of real GDP in the biosciences across states. The values estimate only the effect of NIH funding on the bioscience industry. As the industry grows, it can influence the development of related industries that will attract still more businesses to the region. Additionally, as workers in the bioscience and related industries spend their incomes, they boost consumption activity. Thus, every NIH dollar that goes into the bioscience not only benefits crucial research, but the broader economy as well.

Background

The NIH comprises 27 institutes and centers, each focusing on specific health-related and disease research. This includes the National Cancer Institute and the National Institute of Allergy and Infectious Diseases, the National Eye Institute, and National Heart, Blood, and Lung Institute. Research grants, career development awards, research training and fellowships, and program projects/centers grants are the major award categories. About 10 percent of the budget supports "intramural" research, mostly conducted at NIH laboratories. One of the main centers for intramural research funds is the NIH Clinical Center, the largest hospital for clinical research in the country.

The NIH not only conducts research in its own national labs and clinics, but it is also an important funding source for scientific research in universities, medical schools, hospitals, and research institutions throughout the country and abroad; it supports the training of research investigators and ensures proper communication of medical and health sciences information. The agency reports that "more than 80 percent of its funding is awarded through almost 50,000

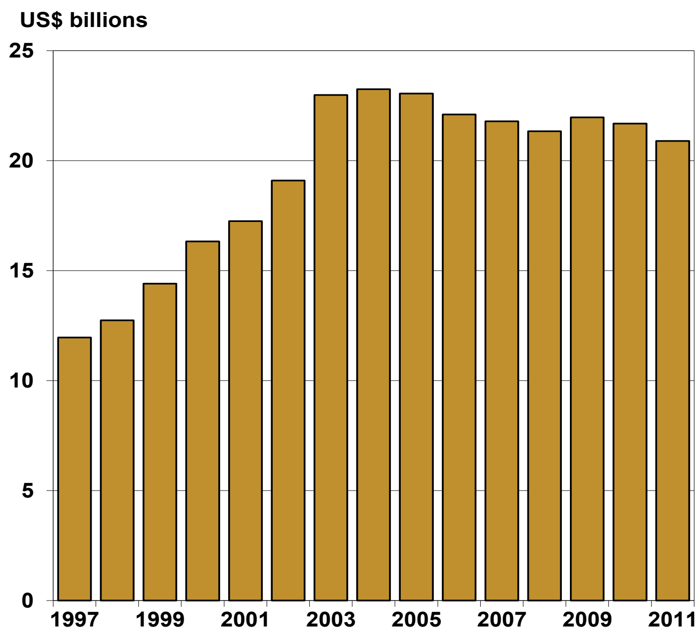
5. See the Methodology for a definition of the bioscience industry.

competitive grants to more than 300,000 researchers at more than 2,500 universities, medical schools, and other research institutions in every state and around the world."[6]

The majority of the NIH budget[7] is spent on funding research. National NIH award funding more than doubled from about $10.9 billion in 1998 to almost $23 billion in 2004. It increased slightly to $24 billion in 2011.

The award funding in real terms (inflation-adjusted) grew steadily from $12.7 billion in 1998, peaked at $23.3 billion in 2004, and then started to decline. In 2011, it was just under $21 billion. Budgetary issues leading to declines in such investment have dramatic consequences on the progress of medical innovation and place significant constraints on economic growth.

Real NIH award funding
2005 dollars



Sources: National Institutes of Health (NIH), Milken Institute.

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6. National Institutes of Health, NIH Budget: Research for the People, http://www.nih.gov/about/budget.htm (accessed August 30, 2012).
7. The National Institute of Health's (NIH) budget in 1998 was $13.7 billion, which increased to $30.9 billion in 2011.

NIH and the Bioscience Industry

While NIH funding provides the nation's financial backbone for medical research and innovation, it also serves as a catalyst for job creation and economic prosperity. NIH research funding created more than 430,000 jobs in 2011 and generated $62.13 billion in new contemporaneous economic activity using an input/output based methodological approach.[8] Estimates show that every $1.00 of NIH fund generates $2.21 in economic output.[9]

Since a majority of the funding is devoted to basic research, it often opens up new therapeutic pathways. From the beginning of the funding period through the introduction of new therapies to the market, NIH funding supports a vast number of jobs, as well as output growth that continues to expand beyond the market introduction phase. Highly skilled jobs are also an element for the development of human capital and bioscience cluster formation.

Industry clusters and their associated support infrastructure are a powerful force in sustaining U.S. competitiveness, especially in the biosciences. Since knowledge is generated, transmitted, and shared more efficiently in close proximity, economic activity based on new ideas has a high propensity to cluster within a geographic area.[10] Regions with thriving bioscience clusters will be less likely to see the economic benefits of those clusters escape to other regions.[11]

The bioscience clustering effect has distinguished the United States from all other nations, creating an unusually fertile environment for R&D. By effectively leveraging public funding from the NIH and other programs to attract private funding, valuable partnerships and research collaborations have been formed, improving the overall productivity of the research enterprise. Successful bioscience clusters are characterized by strategic partnerships between public

8. National Institutes of Health, fact sheet, "NIH. Turning Discovery Into Health: Impacts on U.S. Economy," March 2012, http://www.nih.gov/about/impact/impact_economy.pdf (accessed August 15, 2012).
9. Society for Neuroscience, fact sheet, "National Institutes of Health: The Economic Impact of Investing in Biomedical Research," http://www.sfn.org/siteobjects/published/0000BDF20016F63800FD712C30FA42DD/3D58897B47CD41C67B3DA0D42C272BAF/file/NIH%20Economic%20Impact%20fact%20sheet_2012.pdf (accessed August 17, 2012).
10. Ross DeVol et al., "America's Biotech and Life Science Clusters. San Diego's Position and Economic Contributions," Milken Institute, 2004.
11. Ross DeVol et al., "The Greater Philadelphia Life Sciences Cluster 2009: An Economic and Comparative Assessment," Milken Institute, 2009.

organizations, such as universities, hospitals, medical centers and institutes with private firms. Jointly, they foster cross-disciplinary research of the sort that lends itself to innovation.[12]

Universities are crucial assets in the knowledge-based economy of the 21st century. By effectively converting publicly funded research into private-sector application and developing the talent that the industry requires, universities serve as the building blocks of a bioscience cluster. In addition to offering research labs and highly educated staff, they are also able to attract new research-oriented companies. Joint academic–industry collaborations support research objectives by granting firms access to cutting-edge discoveries and establishing a pathway for hiring top graduates.

The 1980 passage of the Bayh–Dole University and Small Business Patent Act, along with Stevenson–Wydler Technology Innovation Act, enabled researchers and scientists to license technologies and create spinoff companies from research funded by the public sector. Scientists move fluidly across institutions and establishments, passing between academia and the private sector. This flexibility has fostered an R&D environment that produces a high rate of commercialization, especially productive in the biomedical sciences.

To maintain their research functions, universities rely on public-sector funding. One major federal source is the NIH. Other federal programs, such as National Science Foundation (NSF), Small Business Technology Transfer (STTR) and Small Business Innovation Research, are also critical components of academic R&D. The top 10 NIH-funded states in 2011 are displayed in the table below.

12. Jason Owen-Smith et al., "A Comparison of U.S. and European University-Industry Relations in the Life Sciences," *Management Science* 48, no. 1 (2002).

Top 10 NIH-funded states, 2011

State	Real funding (US$ millions)	Real output in bioscience industry (US$ millions)
California	3,152.7	28,328.5
Massachusetts	2,223.7	11,550.7
New York	1,785.9	12,582.2
Maryland	1,486.7	4,149.3
Pennsylvania	1,266.1	10,296.0
Texas	947.7	6,844.0
North Carolina	934.4	10,988.5
Washington	817.3	2,153.7
Illinois	681.2	6,792.7
Ohio	621.4	3,202.3

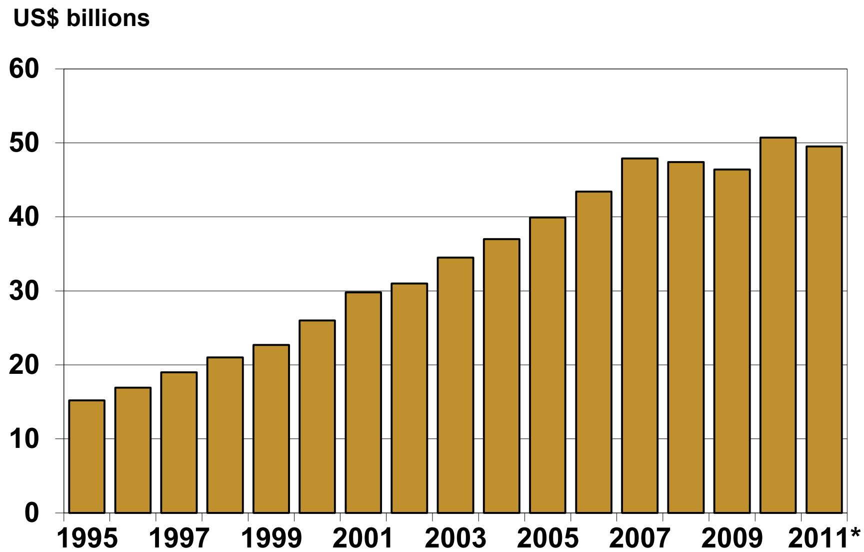
Sources: Bureau of Labor Statistics, Moody's Analytics, National Institutes of Health, Milken Institute.

California tops all states for obtaining NIH funding, followed by Massachusetts, New York, Maryland, and Pennsylvania. California's bioscience industry also is the largest. These states also have well-established bioscience clusters, providing strong evidence that NIH funding has contributed to their formation and growth.

NIH and Private R&D Funding

Private R&D investment also plays an important role in the development of the bioscience industry. The following graph shows that among Pharmaceutical Research and Manufacturers of America (PhRMA) member companies, R&D expenditures increased from about $21 billion in 1998 to $34.5 billion in 2003. PhRMA member companies spend considerably more than the NIH and the gap has been widening over the past 15 years. In 2011, PhRMA member companies spent just under $50 billion, almost $20 billion more on R&D than the total NIH budget. This spending gap may widen further. More ominously, lower NIH investment might cause a substantial decline in private-sector R&D, as the expected rate of return diminishes due to less public funding.

Nominal R&D spending by PhRMA member companies



* Estimated.
Source: Pharmaceutical Research and Manufacturers of America (PhRMA).

The graph portrays a good representation of the overall picture of private R&D investment in the bioscience industry. Even though there is evidence that the gap between the NIH and PhRMA member R&D spending has been increasing, it is of great interest to know the relationship between private R&D and NIH funding.

Previous studies have debated whether NIH funding crowds out or complements private R&D expenditures. Several studies concluded that instead of displacing private R&D, NIH funds are complementary with private dollars. Firms respond to new information from publicly funded basic research and over time increase their own R&D investments. In the pharmaceutical industry, a $1.00 public investment in basic research is estimated to lead to an additional $8.38 of private R&D after eight years.[13] It is also estimated that an additional dollar of federal funding for life sciences research at universities increases private R&D funding by $0.33. The point elasticity (at the average) for private funding to lagged federal funding is 0.51.[14]

13. Andrew A. Toole, "Does Public Scientific Research Complement Private Investment in Research and Development in the Pharmaceutical Industry?" *Journal of Law and Economics*, 50 (2007), pp. 81–104.
14. Margaret E. Blume-Kohout, Krishna B. Kumar, and Neeraj Sood, "Federal Life Sciences Funding and University R&D," National Bureau of Economic Research, July 2009.

Many studies have found a relationship between public and private funding in R&D. This paper utilizes overall industrial R&D spending as a proxy for biosciences industry R&D spending.[15] Our preliminary estimates show that there is a significant positive effect of NIH funding on industrial R&D and that the effect is the greatest at a lag of five to 10 years.

One of the most profound examples of a strong complementary relationship between public and private R&D dollars is the human genome project. NIH funds incentivized more competition between private-sector U.S. companies in the development of new products based on knowledge of genetic sequencing. NIH funds began the foundation for sequencing genomes, which started at a cost of $100 million; today this cost has been reduced to $20,000.[16]

Methodology

This paper establishes a long-term relationship between NIH funding and the size of the bioscience industry, using an econometric model (production function) framework that describes the relationship between inputs (employment, labor skill, capital stock, real NIH funding levels, and private-sector R&D investment for bioscience industries) and output (real GDP for bioscience industries). Again, it uses industrial R&D as a proxy for bioscience industries R&D. The simplest production function model is of the following form:

Real GDP for the bioscience industries = f (employment in bioscience industry, labor skill, capital stock, real NIH funding, Industrial R&D in all industries) + fixed effects for each state + error term

An unbalanced panel data model that specifies lagged values of NIH funding levels and other factors for each of the 50 states and Washington, D.C., over the period 1984–2011 is used. State-level data provide us an experimental laboratory for investigating the efficacy of NIH investment in medical research in relation to private-sector bioscience activities. This paper

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15. Due to data limitations, we had to use industrial R&D instead of R&D in bioscience industries. In 2007, biotechnology and pharmaceuticals R&D was almost 17 percent of industrial R&D. For the same year, the correlation between biotechnology and pharmaceuticals R&D with the rest of industrial R&D investment was 0.61 and significant at 5 percent level

16. Dr. Everett Ehrlich, "An Economic Engine: NIH Research, Employment, and the Future of the Medical Innovation Sector."

estimates the impact of real NIH funding on subsequent private biosciences growth as measured by real GDP in bioscience industries.

The following table provides a summary on data collection and sources:

Data collection

Variable	Definition	Source
Output	Real GDP of bioscience industries*	Bureau of Labor Statistics, Moody's Analytics, Milken Institute.
Employment	Employment in the biosciences	Bureau of Labor Statistics, Moody's Analytics, Milken Institute.
Skilled labor force	% employed in S&E** with Ph.D.s	National Science Foundation, Moody's Analytics, Milken Institute.
Capital stock	Public expenditure on capital outlays	Bureau of Economic Analysis, Moody's Analytics,U.S. Census.
Real NIH funding	Award amounts in 2005 dollars	National Institutes of Health, National Science Foundation, Milken Institute.
Industrial R&D	Total Industrial R&D	National Science Foundation.

* For detailed NAICS codes, see table below.

** Science and engineering.

Source: Milken Institute.

The bioscience industry was defined using the 2007 North American Classification System (NAICS) by the federal Office of Management and Budget (OMB).

The table below gives an overview of the 2007 NAICS-based industry classifications used in defining the bioscience industry, which encompasses biotechnology, pharmaceuticals, medical devices, and life sciences R&D industries.

Defining the bioscience industry

NAICS code	Definition
325412	Pharmaceutical preparation manufacturing
325411	Medicinal and botanical manufacturing
325413	In-vitro diagnostic substance manufacturing
325414	Other biological product manufacturing
339112	Surgical and medical instrument manufacturing
339113	Surgical appliance and supplies manufacturing
339114	Dental equipment and supplies manufacturing
339115	Ophthalmic goods manufacturing
339116	Electromedical apparatus manufacturing
5417*	Scientific research and development

* Includes only the life sciences portion (541711 and 22% of 541712)

Source: U.S. Census Bureau.

This study used aggregated output (real GDP) and employment from these NAICS codes.

Labor skill was measured by the percent of employment in science and engineering with a Ph.D. Bioscience industry supports numerous jobs in science and engineering. We could not find consistent data for all states and across time for the quality of labor employed within the bioscience industry' hence, the science and engineering variable was used as a proxy.

Capital stock variable was measured using national, state and local government fixed assets:

a) Equipment and software
b) Structures

It was further converted into real terms, and state share of total U.S. expenditures of state government capital outlays was used to break out the above.

Preliminary findings

Preliminary results show that the long-term effect of a $1.00 increase in NIH funding will increase the size (output) of the bioscience industry by at least $1.70.

Model 1 in the following table shows the result from a traditional production function framework in which the output (GDP) in the bioscience industry depends on the contemporaneous effects of employment in the industry, quality of labor, capital stock, industrial R&D spending, and the NIH funding.[17] The above estimates show that every 1.00 percent increase in NIH funding increases output in the bioscience industry by 0.25 percent. Using average values of real output and real NIH funding, the above result implies that $1.00 in real NIH funding increases that year's real output by $ 1.70. However, the long-term effect of NIH funding is spread over time. Any funding today creates output in subsequent years; thus, there is a lagged effect of NIH funding that captures the true value.

In order to incorporate longer-term effects, we specified alternative specifications in models 2–5. As evident from the table below, model 2 specifies a five-year moving average term for the

[17] All variables were transformed into logarithms in the regression.

real NIH variable. Similarly, models 3–5 respectively incorporate a 10-, 15-, and 20-year moving average term. These alternative specifications help to gauge the long-term effects. Models 2–5 show that real NIH funding has a positively significant long-term effect on real output. More precisely, the various specifications of the models explain over 92 percent of the variation in real GDP in the biosciences across states.

Coefficients (standard errors) from a production functions specification

(includes both employment in bioscience industry and state fixed-effects)
Dependent variable is logarithm of real GDP in the biosciences

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Log (Employment in bioscience industries)	1.18 (0.08)*	1.15 (0.09)*	1.20 (0.11)*	1.28 (0.12)*	1.13 (0.15)*
Log (% Employed S&E with Ph.D.)	0.20 (0.05)*	0.19 (0.05)*	0.16 (0.07)*	0.20 (0.09)*	0.06 (0.06)
Log (Capital stock)	0.38 (0.07)*	0.33 (0.07)*	0.25 (0.07)*	0.18 (0.07)*	0.09 (0.06)
Log (real Industrial R&D spending)	0.10 (0.03)*	0.09 (0.03)*	0.10 (0.04)*	0.08 (0.03)*	0.02 (0.02)
Log (real NIH funding)	0.25 (0.05)*				
Log (real NIH funding 5-year moving average)		0.29 (0.05)*			
Log (real NIH funding 10-year moving average)			0.32 (0.05)*		
Log (real NIH funding 15-year moving average)				0.33 (0.05)*	
Log (real NIH funding 20-year moving average)					0.39 (0.05)*
Constant	1.76 (0.91)**	1.84 (0.91)*	0.84 (1.15)	1.08 (1.33)	2.64 (1.47)**
Total observations	1348	1349	1149	899	650
R^2	0.93	0.92	0.93	0.93	0.94
F-Statistic	151.64	144.58	96.17	67.15	44.35
Probability > F	0.0000	0.0000	0.0000	0.0000	0.0000

* Significant at 5% level.

** Significant at 10% level.

Source: Milken Institute.

Evaluating at the average values, the table also implies that for every $1.00 spent by the NIH, the output in the bioscience industry increases $2.15 (for a five-year moving average model) to $3.15 (for a 15-year moving average model) and potentially more. So as the lagged effect increases, the long-term effects are greater. This suggests that states that were early recipients of NIH funding experienced a relatively higher magnitude of growth in bioscience industry. Actually, there is evidence to support this hypothesis. Except for one state, in 1992, the top 10 recipients of real NIH funding are also the top 10 recipients in 2011. If we consider the output of bioscience industry in these states in 2011, they are also among the top.

The specification is likely to have an endogeneity issue. In other words, the first round of NIH funding encourages more employment, which subsequently increases output. So there is a direct effect of NIH on output and indirect effect through employment. In order to resolve this issue, econometric literature uses instruments (proxies) that are correlated with employment, but not with NIH. In this preliminary study, we are not incorporating instruments; but to see the effect of NIH without the employment variable, we dropped the employment variable from the following model. The value of the real NIH spending increases significantly for all different model specifications, suggesting that the long-term impact of NIH funding on output in the biosciences industry could be substantially higher.

Coefficients (standard errors) from a production functions specification

(includes state fixed-effects)

Dependent variable is logarithm of real GDP in the biosciences

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Log (Employment in bioscience industries)	-	-	-	-	-
Log (% Employed S&E with Ph.D.)	0.18 (0.08)*	0.17 (0.07)*	0.21 (0.08)*	0.38 (0.10)*	0.15 (0.06)*
Log (Capital stock)	0.52 (0.10)*	0.44 (0.10)*	0.34 (0.10)*	0.20 (0.10)*	0.08 (0.07)
Log (real Industrial R&D spending)	0.15 (0.05)*	0.13 (0.05)*	0.13 (0.06)*	0.05 (0.04)	0.02 (0.04)
Log (real NIH funding)	0.41 (0.07)*				
Log (real NIH funding 5-year moving average)		0.46 (0.07)*			
Log (real NIH funding 10-year moving average)			0.52 (0.08)*		
Log (real NIH funding 15-year moving average)				0.56 (0.07)*	
Log (real NIH funding 20-year moving average)					0.61 (0.07)*
Constant	7.39 (1.16)*	7.29 (1.15)*	6.79 (1.17)*	8.71 (1.28)*	8.83 (1.33)*
Total observations	1348	1349	1149	899	650
R^2	0.75	0.74	0.73	0.67	0.70
F-Statistic	56.65	52.92	45.55	31.64	22.40
Probability > F	0.0000	0.0000	0.0000	0.0000	0.0000

* Significant at 5% level.

** Significant at 10% level.

Source: Milken Institute.

Similarly, NIH funding can influence private R&D in the bioscience industry. Since we did not find consistent data for all states over time, we used overall industry R&D. We have preliminary results to indicate that NIH funding has a significant effect on industrial R&D investment.

Conclusion and Scope for Future Research

This paper establishes a significant long-term effect of real NIH funding on the size of the bioscience industry. Preliminary findings also suggest that the effect on states that experienced initial NIH funding many years in the past has also been remarkable, relative to other states.

This paper utilized state-level data covering more than 25 years to establish longer-term relationships between NIH funding and the size of the bioscience industry. A work in progress, this paper acknowledges that there is considerable scope for refining the methodology. There are two main issues to address in our future research:

1) Real NIH funding can influence the number of jobs created in the industry or the quality of labor. Thus, real NIH funding has two effects on the bioscience industry: the direct effect through an increase in output; and the indirect effect through increase in employment, private R&D, and skill mix, all of which affect output. Dynamic bioscience and economic growth depend, for example, on continued investment in NIH funding (flow). This growth in bioscience industries subsequently increases private R&D funding. In summary, NIH funding has an indirect impact on subsequent private R&D funding in these industries. In order to account for this effect, we propose to deploy an endogenous growth estimation approach, which assumes that factors influencing economic performance are determined within the system and simultaneously interact with each other.

2) Preliminary estimates show that there is a lagged effect of NIH and private funding on output. We plan to perform a Granger Causality test or other methods to determine exact lag-lengths. We specified linear and moving-average models in this paper. It is also possible that lag-lengths follow a non-linear specification. A suggested approach will be to specify a polynomial distributed lag model.

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