Technology Transfer at U.S. Federal Laboratories:

R&D → Disclosures → Patent Applications

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Albert N. Link

University of North Carolina at Greensboro

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Albert N. Link

Department of Economics

University of North Carolina at Greensboro

anlink@uncg.edu

Abstract

This paper describes relationships within the technology transfer process at U.S. federal laboratories. Using federal laboratory data on R&D, invention disclosures, and patent applications, aggregated to the agency level, quantitative estimates of the relationship among these metrics are presented. The policy-related finding is that a 10 percent increase in R&D per 100 scientists is associated with between a 1.52 percent and a 2.04 percent increase in patent applications per 100 scientists.

Keywords: Technology transfer, Federal laboratory, R&D, STEM employees, Policy evaluation
JEL Codes: H42, O33, O38

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I. Introduction

In the early 1970s, and then again in the late 1970s and early 1980s, the U.S. economy experienced a significant slowdown in productivity growth.¹ In response to this slowdown, which also was occurring in most industrialized nations at that time, U.S. President Jimmy Carter initiated a Domestic Policy Review in 1979. The Review charged Congress to pursue eight corrective policy initiatives, the first of which was to enhance the transfer of information from federal laboratories into the economy (Carter, 1979, p. 64):

Often, the information that underlies a technological advance is not known to companies capable of commercially developing that advance. I am therefore taking several actions to ease and encourage the flow of technical knowledge and information. These actions include [the improvement of] the transfer of knowledge from Federal laboratories.

Soon thereafter, Congress passed the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480).

It is the purpose of this Act to improve the economic, environmental, and social well-being of the United States by ... promoting technology development through the establishment of centers for industrial technology [within Federal laboratories and] stimulating improved utilization of federally funded technology developments by State and local governments and the private sector ... It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive

¹ See Bozeman and Link (2015), Leyden and Link (2015) and Link and Oliver (2020) for an in-depth discussion of the productivity slowdown and the various policy responses initiated by Congress in the early 1980s. See also Link and Oliver (2020) for an elaboration of the enabling legislation discussed in this section of the paper.

where appropriate to transfer Federally owned or originated technology to State and local governments and to the private sector.

Several amendments followed the passage of the Stevenson-Wydler Act.² In particular, the Federal Technology Transfer Act of 1986 (Public Law 99-502) established,³ among other things, the Federal Laboratory Consortium for Technology Transfer (FLC), and the then National Bureau of Standards (which later became the National Institute of Standards and Technology, NIST) was to be the FLC's host laboratory. The FLC was charged to:

... develop and (with the consent of the Federal Laboratory concerned) administer techniques, training courses, and materials concerning technology transfer to increase the awareness of Federal laboratory employees regarding the commercial potential of laboratory technology and innovations ...

While not an amendment to the Stevenson-Wydler Act, technology transfer from federal laboratories was also emphasized in *U.S. Technology Policy*, issued by President George H. W. Bush in 1990 (Executive Office of the President, 1990, pp. 1-6).⁴

A nation's technology policy is based on broad principles that govern the allocation of technological resources ... The goal of U.S. technology policy is to make the best use of technology in achieving the national goals of improved quality of life for Americans, contained economic growth, and national security ... While the government plays a critical role in establishing an economic environment to encourage innovation, the private sector has the principal role in identifying and utilizing technologies for commercial

² A detailed discussion of the amendments to the Stevenson-Wydler Act is in Link and Oliver (2020). See footnote 10 below.

³ As Link, Siegel and van Fleet (2011) showed for Sandia National Laboratories and for the National Institute of Standards and Technology (NIST), patenting activity did not increase in response to the Stevenson-Wydler Act. Patenting activity did increase after the passage of the Federal Technology Transfer Act, which included the following guideline: "The head of the agency or his designee shall pay at least 15 percent of the royalties or other income the agency receives on account of any [patented] invention to the inventor (or co-inventors) if the inventor (or each such co-inventor) was an employee of the agency at the time the invention was made."

⁴ Arguably, *U.S. Technology Policy* is the first complete U.S. statement on technology policy since the productivity slowdown in the 1970s and early 1980s.

products and processes ... Government policies can help establish a favorable environment for private industry [by improving] the transfer of Federal laboratories' R&D results to the private sector [and by expediting] the diffusion of the results of Federally-conducted R&D to industry, including licensing of inventions ...

Finally, the National Technology Transfer and Advancement Act of 1995 (Public Law 104-113) strengthened the purpose of the Stevenson-Wydler Act:

Bringing technology and industrial innovation to the marketplace is central to the economic, environmental, and social well-being of the people of the United States.

Surprisingly, the academic and policy literatures related to technology transfer from federal laboratories is limited, perhaps due to laboratory imposed access barriers to information about mechanisms and metrics associated with technology transfer activities.^{5,6} However, limited information about the technology transfer activities of federal laboratories, aggregated to the federal agency level, is available through agency technology transfer reports which are submitted annually to the Technology Partnerships Office (TPO) at NIST.⁷ The information that is available has only begun to be studied systematically.⁸

The remainder of this paper is outlined as follows. In Section II, selected technology transfer mechanisms are described as a step toward understanding and quantifying the technology transfer process in a federal laboratory. In Section III, an empirical model is presented; the model is used to quantify specific relationships within the technology transfer process. In Section IV, the federal agency data used to estimate the model are described. The empirical

⁵ Research access barriers exist even when technology transfer studies are commissioned by NIST. See the related discussion in RTI International (2019).

⁶ The relevant academic and policy literatures related to technology transfer in federal laboratories is reviewed in Link and Oliver (2020).

⁷ These annual reports are required under the Technology Transfer Commercialization Act of 2000 (Public Law 106-404).

⁸ One of the first systematic efforts to study technology transfer in federal laboratories using these data is by Link and Oliver (2020).

results from the estimation of the model are presented and discussed in Section V. The paper concludes in Section VI with qualifying remarks about the statistical findings presented in this paper along with a suggested roadmap for future research.

II. Technology Transfer Mechanisms

Renewed research and policy attention to technology transfer activities in federal laboratories was initiated through President Barrack Obama’s 2011 *Presidential Memorandum—Accelerating Technology Transfer and Commercialization of Federal Research Support of High Growth Businesses*:⁹

Innovation fuels economic growth, the creation of new industries, companies, jobs, products and services, and the global competitiveness of U.S. industries. One driver of successful innovation is technology transfer, in which the private sector adapts Federal research for use in the marketplace . . . I direct that [Federal laboratories] establish goals and measure performance, streamline administrative processes, and facilitate local and regional partnerships in order to accelerate technology transfer and support private sector commercialization.

Building on the theme of President Obama’s Memorandum, President Donald Trump, in his *The President’s Management Agenda* (Trump, undated, p. 47), set forth the goal to: “Improve the transfer of technology from federally funded research and development to the private sector to promote U.S. economic growth and national security” for modernizing government for the 21st Century. Specifically (p. 47):

For America to maintain its position as the leader in global innovation, bring products to market more quickly, grow the economy, and maintain a strong national security innovation base, it is essential to optimize technology transfer and support programs to increase the return on investment (ROI) from federally funded R&D.

⁹ The Board on Science and Technology Policy at the National Academies (the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine) recently commissioned a study on Advancing Commercialization from the Federal Laboratories. See, https://sites.nationalacademies.org/PGA/step/PGA_191994 (accessed October 26, 2020).

Of course, to embrace these presidential initiatives from a research as well as from a policy perspective, and to identify the outcomes associated with the Stevenson-Wydler Act and its amendments, the process of technology transfer in a federal laboratory must first be understood.¹⁰ The shaded areas in Figure 1, which are based on the U.S. Congressional Budget Office (CBO) description of key elements of the technology transfer from federal laboratories, highlight the portions of the technology transfer process in a federal laboratory that are relevant to this study; I refer to these shaded areas as representing the *internal* [my emphasis] portion of the technology transfer process.¹¹

Insert Figure 1 about here

Simply, the technology transfer process begins with the laboratory's investments in research and development (R&D), and some of the results from R&D become inventions (as well as other knowledge-based outputs, such as publications) that are formally disclosed to the laboratory's technology transfer office (TTO) through an invention disclosure form. An invention disclosure form is a vehicle through which the laboratory collects information pertaining to inventions created by the federal and non-federal employees who created an invention using laboratory facilities.¹²

¹⁰ Relevant amendments to the Stevenson-Wydler Act are, according to Schacht (2012): the Federal Technology Transfer Act of 1986 (Public Law 99-502), the 1988 Omnibus Trade and Competitiveness Act (Public Law 100-418), the 1990 Department of Defense Authorization Act (Public Law 101-189), the National Defense Authorization Act for FY1991 (Public Law 101-510), the 1996 Technology Transfer Improvements and Advancement Act (Public Law 104-113), and the Technology Transfer Commercialization Act of 2000 (Public Law 106-404).

¹¹ The GAO illustration of elements of the technology transfer process is intended to emphasize licensing agreements. However, regardless of the output of the technology transfer process being emphasized, the internal portion will be similar if not identical to what I have shaded in the figure.

¹² "The collection of this information is required to protect the United States rights to inventions created using Federal resources. The information collected on the form allows the Government to determine: (1) If an invention has been created; (2) the status of any statutory bar that pertains to the potential invention or that may pertain to the invention in the future. The information collected may allow the Government to begin a patent application process." See, <https://www.federalregister.gov/documents/2019/08/07/2019-16882/proposed-information-collection-nist-invention-disclosure-and-inventor-information-collection> (accessed October 26, 2020).

In an ideal world, as described by Figure 1, the technology transfer process begins with R&D, and then the rest of the process is based on disclosed inventions. Namely: *R&D → Invention disclosures → Patent applications → Patents awarded → Patents licensed*.¹³

The *R&D → Invention disclosures → Patent applications* portions of this process, as shown in the shaded areas in Figure 1, are laboratory specific, meaning that they are internal to the federal laboratory. The *Patents awarded → Patents licensed* portion of the process involves the *external* [my emphasis] portion of the technology transfer process. I refer to this as the external portion because it is influenced by activities external to the laboratory such as the infrastructure of the U.S. Patent and Trademark Office (USPTO), changes in patenting regulations, as well as the cyclical nature of market demand for laboratory-based patented technology.

While a laboratory's R&D budget is the motivating force behind the technology transfer process as described throughout Figure 1, the genesis element of the process is the transition from R&D activity to invention disclosures. Absent invention disclosures there will not be patent applications,¹⁴ and absent patent applications, there will not be licensable patents issued which are the technology transfer vehicle emphasized in Figure 1.¹⁵

Thus, as previously stated, the purpose of this paper is to quantify the laboratory-specific internal portion of the technology transfer model in Figure 1 for the purpose of emphasizing the policy importance of understanding both the *R&D → Invention disclosures* relationship and the *Invention disclosures → Patent applications* relationship. To date, these internal processes have not been systematically quantified across the federal laboratories in U.S. agencies.¹⁶

¹³ It is not unusual for the licensing process to begin at the patent application stage.

¹⁴ The Stevenson-Wydler Act required federal laboratories to establish invention reporting practices.

¹⁵ Another important technology transfer mechanism, although not shown in Figure 1, is CRADAs (Cooperative Research And Development Agreements), and patent applications can result from CRADAs. See, Chen, Link, and Oliver (2018).

¹⁶ See Link (2019) for an initial empirical study of the relationship among elements of the technology transfer process relevant to one federal laboratory, NIST.

III. Empirical Model

The empirical model considered in this paper is based on the internal laboratory relationships shown in the shaded areas of Figure 1. The first is the *R&D* $\rightarrow$ *Invention disclosures* relationship, and the second is the *Invention disclosures* $\rightarrow$ *Patent applications* relationships.

Consider a model of inventions disclosures within a federal laboratory of the form:

$$(1) \quad \textit{Invention disclosures} = f(HC, TC)$$

where *HC* refers to the human capital and *TC* refers to technical capital. A reduced form of equation (1) is:

$$(2) \quad \textit{Invention disclosures per 100 scientists} = F(TC)$$

where the variable *Scientists* is used to approximate *HC*, and the functional form of $f(\cdot)$ need not be the same as $F(\cdot)$.

As previously mentioned, and as discussed in the following section of this paper, the data that are available on technology transfer in federal laboratories are laboratory data aggregated to the agency level. Using agency level metrics, equation (2) might be expressed as:

$$(3) \quad \textit{Invention disclosures per 100 scientists} = F(\textit{R\&D per 100 scientists}, \mathbf{X})$$

where the variable *R&D per 100 scientists* approximates *TC* and where vector $\mathbf{X}$ includes agency fixed effects.¹⁷ And along with equation (3), the second component of the internal laboratory relationship might be expressed as:

$$(4) \quad \textit{Patent applications per 100 scientists} = F(\textit{Invention disclosures per 100 scientists}, \mathbf{X})$$

¹⁷ There could be portions of *TC* that are not related to the laboratory's R&D budget, and part of the R&D budget may include investments in *HC*. Imprecisions associated with the measures of *HC* and *TC* used to estimate these two equations are discussed in Section VI below.

IV. Data and Descriptive Statistics

The TPO at NIST assembles each agency’s annual technology transfer report into a composite annual report entitled *Federal Laboratory Technology Transfer [Fiscal Year]: Summary Report to the President and the Congress*.¹⁸ From these annual reports, agency data are available on *Invention disclosures* and *Patent applications* by fiscal year (FY). Data on these two technology transfer metrics are available from FY 2003 through FY 2016 for each of 11 agencies.¹⁹ However, there are four agencies that are R&D and invention disclosure intensive: the Department of Defense (DOD), Department of Energy (DOE), Health and Human Services (HHS), and National Aeronautics and Space Administration (NASA). These four agencies accounted for an average of just over 91 percent of all agency R&D and nearly 92 percent of all agency invention disclosures—the key variables in Figure 1 and in the analysis that follows—over the FY 2003 through FY 2016 time period.

The data on *R&D* used in this paper are shown in Table 1, the data on *Invention disclosures* are in Table 2, the data on *Scientists* are in Table 3, and the data on *Patent applications* are in Table 4.

Insert Tables 1, 2, 3, and 4 about here

Table 5 provides a definition of how the variables in equations (3) and (4) are measured. Descriptive statistics on these variables are in Table 6.

Insert Tables 5 and 6 about here

V. Empirical Results

¹⁸ See, <https://www.nist.gov/tpo/reports-and-publications> (accessed October 26, 2020).

¹⁹ These agencies are U.S. Department of Agriculture, Department of Commerce, Department of Defense, Department of Energy, Health and Human Services, Department of Homeland Security (data are available for limited years), Department of Interior, Department of Transportation, Department of Veterans Affairs, Environmental Protection Agency, and National Aeronautics and Space Administration.

The regression results from the separate estimation of equations (3) and (4) are in Table 7; the regression results from estimating equations (3) and (4) as a system are in Table 8.²⁰ The variables enter the models as natural logarithms so that the slope coefficients can be interpreted as elasticities.

Insert Tables 7 and 8 about here

The OLS regression results from equation (3) are reported in column (1) of Table 7. They suggest that a 10 percent increase in the R&D intensity of an agency, that is in *R&D per 100 scientists*, is associated with a 4.63 percent increase in *Invention disclosures per 100 scientists*. R&D investments fuel scientific creativity as measured by invention disclosures. The results from equation (4) are in column (2) of Table 7. They suggest that a 10 percent increase in *Invention disclosures per 100 scientists* is associated with a 4.40 percent increase in *Patent applications per scientists*. Not all inventions disclosed to a laboratory's TTO, as shown in Figure 1, are selected for patenting.²¹ The empirical results from equations (3) and (4), reported in Table 7, together suggest that a 10 percent increase in *R&D per 100 scientists* is associated with a 2.04 percent increase in *Patent applications per 100 scientists*.²²

The regression results in column (3) and column (4) in Table 7 show that there is not, in the specifications considered, a direct relationship from *R&D* $\rightarrow$ *Patent applications* among the laboratories in the four agencies studied. The estimated coefficient on *R&D per 100 scientists* is not statistically significant in either equation.

²⁰ In separate regressions I estimated equations (3) and (4) using data for the deleted seven agencies. Collectively, they represent less than 10% of the R&D in federal laboratories. The models do not hold for these agencies. These results are available from the author on request.

²¹ Choudhry and Ponzio (2020) suggested a new technology transfer metric for federal agencies to consider, namely, a Filing Ratio. Their Filing Ratio for an agency equals the number of new patent applications divided by the number of new inventions disclosed for a given period of time. Link and Oliver (2020) estimated a Filing Ratio for the four agencies considered in this paper over the period of FY 2008 through FY 2015. Link and Oliver report the following: DOD = 0.862, DOE = 0.564, HHS = 0.678, and NASA = 0.085.

²² Since a 10% increase in *R&D per 100 scientists* is associated with a 4.63% increase in *Invention disclosures per 100 scientists*, and since a 10% increase in *Invention disclosures per 100 scientists* is associated with a 4.40% increase in *Patent applications per 100 scientists*, then a 10% increase in *R&D per scientists* is associated with a 2.04% $((4.63 \times 4.40)/10)$ increase in *Patent applications per 100 scientists*.

The regression results from estimating equations (3) and (4) as a system are in Table 8. The 2SLS regression results suggest that a 10 percent increase in the R&D intensity of an agency, that is in *R&D per 100 scientists*, is associated with a 4.70 percent increase in *Invention disclosures per 100 scientists*. The results from equation (4) suggest that a 10 percent increase in *Invention disclosures per 100 scientists* is associated with a 3.23 percent increase in *Patent applications per scientists*. Together, the empirical results from equations (3) and (4) suggest that a 10 percent increase in *R&D per 100 scientists* is associated with a 1.52 percent increase in *Patent applications per 100 scientists*.²³

Other variables in equation (3) and equation (4) are agency fixed effect controls to account for agency differences in emphasis on technology transfer per se, a fiscal year (*FY*) variable to control for trend and autoregressive patterns, and a variable to control for recessionary (*Recession*) effects on scientific activities including budgets.

VI. Concluding Remarks

Patent applications by a laboratory are, based on the results presented in Tables 7 and 8, a prerequisite for patents issued to a laboratory and in some instances a prerequisite to patent licenses. It is through the patent licensing process that federal laboratory technologies are transferred to private sector firms and/or public sector organizations as shown in Figure 1. Thus, quantifying the path from R&D spending to patent application not only informs public policy but also emphasizes the quantitative importance of such networks.

For example, if technology transfer from federal laboratories is to continue to increase over time, as is important for national economic growth, then it is necessary for invention disclosures to continue to increase over time. And, for invention disclosures to continue to increase over time, R&D funding must also continue to increase over time. If R&D funding to a laboratory does not

²³ Since a 10% increase in *R&D per 100 scientists* is associated with a 4.70% increase in *Invention disclosures per 100 scientists*, and since a 10% increase in *Invention disclosures per 100 scientists* is associated with a 3.23% increase in *Patent applications per 100 scientists*, then a 10% increase in *R&D per scientists* is associated with a 1.52% $((4.70 \times 3.23)/10)$ increase in *Patent applications per 100 scientists*.

increase over time, that is if the resources requisite for new scientific ideas as reflected through new invention disclosures do not increase over time, then eventually technology transfer efforts might stagnate or even decline.^{24,25}

As obvious as this argument in support of continued R&D funding in federal laboratories is, one should be cautious in generalizing from the quantitative findings presented in this paper. The data studied in this paper represent federal laboratory activity aggregated to the agency level. Each federal laboratory is unique in its mission, and it is unique in the manner in which its TTO is organized to determine patenting priorities. Thus, one should not expect that the quantitative relationships presented in Tables 7 and 8 will hold for each individual laboratory. Also, the strength of the relationships considered in this paper are dependent on the reduced form specification for equations (3) and (4). Additional research to develop and estimate structural models is certainly warranted and encouraged.

In addition, available technology transfer metrics have not been precisely measured, and not all relevant variables that support the technology transfer process are even available. The only measure of an agency's technical capital (*TC*) is its R&D budget, and embodied in an R&D budget are expenditures for scientists. Thus, R&D budget data overstate relevant *TC*, and accordingly, human capital (*HC*) is somewhat double counted.²⁶ Caveats aside, the statistical analysis in this paper does emphasize the need for additional academic and policy research on the role of R&D and on the role of invention disclosures (i.e., scientific creativity) in federal laboratories.

Laboratory specific information on technology transfer metrics is difficult to obtain as documented in the recent study of laboratory technology transfer activity by RTI International

²⁴ Recall that President Obama's 2011 Memorandum called for "accelerating technology transfer."

²⁵ New invention disclosures might decline even in the absence of continued or even increasing R&D. Bloom et al. (2020, p. 1138) make the point through examples, although mostly from the private sector, that good ideas are becoming harder to find, and they conclude that: "[o]ur robust finding is that research productivity is falling sharply everywhere we look."

²⁶ See Link and Scott (2019a, 2019b) for an illustration of this fact for NIST.

(2019) under the sponsorship of NIST. Thus, future research related to technology transfer in federal laboratories might proceed through interview-based case studies. Excellent examples of such an interview approach are described in IDA (2013a, 2013b).²⁷

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²⁷ See also, Link and Scott (2019c).

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Figure 1
Elements of the Technology Transfer Process in a Federal Laboratory

Source: Based on GAO (2018, p. 11).

Table 1
R&D Budgets (millions \$2019) by Fiscal Year and by Agency

Agency	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
DOD	80788	87749	90731	92946	96230	96856	96124	96963	90720	83798	72426	72097	71253	77264
DOE	11518	11593	11130	10740	11004	11657	12152	12674	12239	12167	11829	13002	15407	15927
HHS	37735	37949	37665	36253	36077	34904	36639	37144	35758	35310	32933	33248	32322	34025
NASA	14553	14375	13710	14131	14106	13345	10367	10833	10434	12734	12154	12742	12224	14086

Source: <https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd#>

Table 2
Invention Disclosures by Fiscal Year and by Agency

Agency	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
DOD	1332	1369	534	1056	838	1018	831	698	929	1078	1032	963	781	874
DOE	1469	1617	1776	1694	1575	1460	1439	1616	1820	1661	1796	1588	1645	1760
HHS	472	461	452	442	447	437	353	337	351	352	320	351	321	320
NASA	1485	1612	1682	1749	1514	1324	1412	1735	1748	1656	1627	1701	1550	1554

Source: <https://www.nist.gov/tpo/reports-and-publications>

Table 3
Scientists by Fiscal Year and by Agency

Agency	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
DOD	8993	8627	8768	8662	8962	9042	9640	10701	11171	11571	11759	12009	11935	12636
DOE	4880	4747	4663	4562	4502	4634	4763	4928	4877	4731	4629	4476	4501	4559
HHS	12137	11967	11771	11558	11571	11909	12620	13246	13546	13676	13861	13988	14311	16566
NASA	11017	11355	11173	11109	11244	11485	11555	11751	11821	11594	11564	11430	11214	11191

Source: <https://www.fedscope.opm.gov/employment.asp>

Table 4
Patent Applications by Fiscal Year and by Agency

Agency	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
DOD	810	517	354	691	597	590	690	436	844	1013	942	916	884	941
DOE	866	661	812	726	693	904	775	965	868	780	944	1144	949	999
HHS	279	216	230	166	261	164	284	291	272	233	230	216	222	269
NASA	231	207	209	142	127	122	141	150	128	130	150	140	129	129

Source: <https://www.nist.gov/tpo/reports-and-publications>

Table 5
Definition of the Variables in Equations (3) and (4)

Variable	Definition
<i>Invention disclosures</i>	The number of invention disclosures per fiscal year by agency as reported by the Technology Partnerships Office at NIST; see Table 2.
<i>Scientists</i>	The number of STEM occupation employees per fiscal year by agency, measured in hundreds, as reported by the Office of Personnel Management; see Table 3.
<i>R&D</i>	The R&D budget per fiscal year by agency, measured in millions \$2019, as reported by the American Association for the Advancement of Science; see Table 1.
<i>Patent applications</i>	The number of patent applications per fiscal year by agency as reported by the Technology Partnerships Office at NIST; see Table 4.
<i>Agency controls</i>	Binary variables for DOD, DOE, and HHS; NASA fixed effects are captured in the intercept term.
<i>FY</i>	The fiscal year (FY) count variable; accounts for time trends.
<i>Recession</i>	Equals 1 for the years of the Great Recession (FY 2007 – FY 2010), and 0 otherwise

Notes: STEM occupation employees are those employees in an agency who are trained and working in the fields of Science, Technology, Engineering, and Mathematics. The variables *Invention disclosures per Scientists*, *R&D per Scientists*, and *Patent applications per Scientists* are measured as natural logarithms.

Table 6
Descriptive Statistics on the Variables in Equations (3) and (4) by Agency
Mean, (Standard deviation), [Maximum, Minimum]

Variable	Agency			
	DOD (n=14)	DOE (n=14)	HHS (n=14)	NASA (n=14)
<i>Invention disclosure</i>	952.36 (225.08) [534, 1369]	1636.86 (124.95) [1439, 1820]	386.86 (60.04) [320, 472]	1596.36 (130.04) [1324, 1749]
<i>Scientists (00s)</i>	103.20 (14.95) [86.27, 126.36]	46.75 (1.51) [44, 76, 49.28]	130.52 (14.06) [115.58, 165.66]	113.93 (2.46) [110.17, 118.21]
<i>R&D</i>	86138.93 (9783.18) [71253, 96963]	12359.93 (1535.81) [10740, 15927]	35568.71 (1858.62) [32322, 37949]	12842.43 (1465.71) [10367, 14553]
<i>Patent applications</i>	730.36 (207.71) [354, 1013]	863.29 (132.79) [661, 1144]	238.07 (40.47) [164, 291]	152.50 (35.66) [122, 231]

Note: The variable *Scientists* is measured in 100s of STEM occupation employees.

Table 7
 OLS Regression Results from Equations (3) and (4), n=56
 (standard errors in parentheses)

Variable	(1) <i>ln(Invention disclosures per 100 scientists)</i>	(2) <i>ln(Patent applications per 100 scientists)</i>	(3) <i>ln(Patent applications per 100 scientists)</i>	(4) <i>ln(Patent applications per 100 scientists)</i>
<i>ln(R&D per 100 scientists)</i>	0.4630 (0.1787)**	--	-0.1034 (0.2298)	0.1386 (0.2092)
<i>ln(Invention disclosures per 100 scientists)</i>	--	0.4397*** (0.1578)	0.4672*** (0.1699)	--
<i>DOD</i>	-1.3569*** (0.3662)	1.8483*** (0.1095)	2.0673*** (0.4983)	1.01852*** (0.4292)
<i>DOE</i>	0.5166*** (0.1697)	2.2284*** (0.1688)	2.2911*** (0.2212)	2.5224*** (0.1968)
<i>HHS</i>	-1.9689*** (0.1739)	1.0135*** (0.2611)	1.1476*** (0.3957)	0.2119 (0.0254)
<i>FY</i>	-0.0159** (0.0070)	0.0039 (0.0085)	0.0029 (0.0089)	-0.0028 (0.0085)
<i>Recession</i>	-0.0646 (0.0624)	-0.0424 (0.0775)	-0.0372 (0.0790)	-0.0706 (0.0789)
<i>Intercept</i>	31.8936** (14.4417)	-8.6330 (17.3201)	-6.2382 (18.2696)	5.1997 (17.4662)
R-squared	0.9711	0.9731	0.9732	0.9690

Notes: NASA fixed effects are captured in the intercept term.

*** significant at .01-level, ** significant at .05-level, * significant at .10-level

Table 8
2SLS Regression Results from Equations (3) and (4) Estimated as a System, n=56
(standard errors in parentheses)

Variable	(1) <i>ln(Invention disclosures per 100 scientists)</i>	(2) <i>ln(Patent applications per 100 scientists)</i>
<i>ln(R&D per 100 scientists)</i>	0.4704 (0.1562)***	--
<i>ln(Invention disclosures per 100 scientists)</i>	--	0.3229** (0.1546)
<i>DOD</i>	-1.3785*** (0.3201)	1.7925*** (0.1007)
<i>DOE</i>	0.5154*** (0.1478)	2.3397*** (0.1605)
<i>HHS</i>	-1.9676*** (0.1535)	0.8242*** (0.2522)
<i>FY</i>	-0.0158** (0.0063)	0.0040 (0.0076)
<i>Recession</i>	-0.0629 (0.0566)	-0.0472 (0.0665)
<i>Intercept</i>	32.1115** (12.9723)	-8.5663 (15.6137)
F-level	261.76***	262.98***
R-squared	0.9698	0.9699

Notes: NASA fixed effects are captured in the intercept term.

*** significant at .01-level, ** significant at .05-level, * significant at .10-level