A Preliminary Application of an I-O Economic Impact Model to US Federal Laboratory Inventions: 2008-2015

Prepared for the National Institute of Standards and Technology by Lori Pressman, Mark Planting, Robert Yuskavage, Jennifer Bond, and Carol Moylan, July 2018

National Institute of Standards and Technology
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Team: Lori Pressman is an independent business development, licensing and strategy consultant in Cambridge, MA, a former Assistant Director at the MIT Technology Licensing Office and a former Chair of the AUTM Survey Statistics and Metrics Committee. Mr. Mark Planting is former Chief of Research on the use and development of U.S. input-output accounts at the Bureau of Economic Analysis. Mr. Robert Yuskavage is former Associate Director for International Economics at the Bureau of Economic Analysis. Ms. Jennifer Bond is a senior science policy analyst, a Senior Fellow with the Council on Competitiveness and former Director of the Science & Engineering Indicators Program at the National Science Foundation. Ms. Carol Moylan is former Associate Director for Industry Economic Accounts at the Bureau of Economic Analysis.

Acknowledgements: The authors appreciate the interest and support of NIST in applying this model to the licensing activities of the federal laboratories. The model came into being under the leadership of David Roessner, Professor Emeritus, Georgia Institute of Technology. His initial work was sponsored by the Biotechnology Innovation Organization, "BIO".

Contents:

Preface by Jennifer Bond:
Scientific research played an important role in winning World War II. Vannevar Bush stated in his famous *Science the Endless Frontier*, "In this war it has become clear beyond all doubt that scientific research is absolutely essential to national security…There must be more—and more adequate—military research during peacetime. We cannot again rely on our allies to hold off the enemy while we struggle to catch up. Further, it is clear that only the Government can undertake military research; for it must be carried on in secret, much of it has no commercial value, and it is expensive. The obligation of Government to support research on military problems is inescapable." (Vannevar Bush, Science—The Endless Frontier, July 1945 re-publication by the National Science Foundation on the 40th Anniversary 1950-1990 of NSF NSF 90-8, p. 17)

Although widely recognized that Bush emphasized the need for government funding of basic research in universities, he also recognized that government needed to continue funding and performing research itself and much of that would be applied in nature and mission-oriented. "Research within Government represents an important part of our total research activity and needs to be strengthened and expanded after the war. Such expansion should be directed to fields of inquiry and service which are of public importance and are not adequately carried on by private organizations," (Ibid., p. 20).

While acknowledging the need for secrecy for some military and other national security research, Bush also pushed for declassification of as much research as possible; encouraged wide publication and patenting to encourage the dissemination of new scientific and technological advances into the public sphere. (Ibid, pp 28, and 38) He stated, "Basically, there is no reason to believe that scientists of other countries will not in time rediscover everything we now know which is held in secrecy. A broad dissemination of scientific information upon which further advances can readily be made furnishes a sounder foundation for our national security than a policy of restriction which would impede our own progress although imposed in the hope that possible enemies would not catch up with us. ...Our ability to overcome possible future enemies depends upon scientific advances which will proceed more rapidly with diffusion of knowledge than under a policy of continued restriction of knowledge now in our possession," (Ibid., p. 29).

As noted in the Foreword by Erich Bloch of the republished Bush report, "as political conflict among the great powers diminishes, the major area for world competition is increasingly becoming economic, and in this new global economy, which runs on ideas and innovation, knowledge is the critical resource." This is even more true today.

Over the years, it has become increasingly important to make sure that both the federally-funded and federally-performed research which can be disseminated via publications, patents and licenses be disseminated into the public domain and economy both as a way of encouraging the growth in our economy and enhancing our national security.

The Bayh-Dole Act of 1980 has successfully motivated universities and faculty members to take an active role in commercializing technology and increased the interest in commercializing the technologies and discoveries emanating from federal labs. In both settings, it is important to remember the original missions of both universities and federal laboratories are for the public good and not all discoveries will be targets for commercialization. A recent article by Woodell and Smith notes that revenue generation is not the primary motivation for university technology commercialization and offers several recommendations to improve the role of technology transfer in universities some of which might be applicable to technology management in federal labs. (James K Woodell and Tobin L. Smith, "Technology Transfer for all the Right Reasons," *Technology and Innovation* Vol. 18, pp. 295-304, National Academy of Inventors, 2017).

Nonetheless there is current policy interest in accelerating the pace of technology transfer of federally-funded and performed science and technology in both universities and federal laboratories.

President Trump designated "Improve Transfer of Federally-Funded Technologies from Lab-To-Market" as a Cross Agency Priority (CAP) Goal In his "President's Management Agenda" and noted that, "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."

The Commerce Department's National Institute of Standards and Technology (NIST) and the White House Office of Science and Technology Policy (OSTP) are co-leading the Lab-to-Market cross agency priority (CAP) goal. To carry out these efforts, NIST began the Return on Investment (ROI) Initiative at an event titled "Unleashing American Innovation" to streamline and accelerate the transfer of technology from federal laboratories and federally-funded R&D at universities.

In their opening remarks at the "Unleashing American Innovation Symposium" on April 19, 2018 which launched NIST's Return on Investment (ROI) Initiative, Secretary of Commerce Wilbur Ross and Under Secretary and Director of NIST Dr. Walter Copan noted that we are in an era of unprecedented global competition which presents new opportunities as well as threats and that the role of Federal R&D is essential for our economic growth and national security. Secretary Ross suggested that universities could share their best practices of technology transfer with managers at federal labs and challenged universities, federal agencies and laboratories and industry to improve and accelerate their efforts to transfer and translate new technologies into new products and services developed in the United States. Under Secretary Copan said the goal of this initiative is to maximize the transfer of federal investment in science and technology into (increased) value for America.

One of the objectives of NIST's ROI initiative is: "Better metrics and methods to evaluate the ROI outcomes and impacts arising from Federal R&D investment." This research paper is one of the first steps in this effort and can act as a benchmark to measure progress.

Summary:
An input-output "I-O" approach was used to estimate the economic impact of federal laboratory[1] "FL" licensing under two different sets of assumptions. The assumptions are described and preliminary estimates provided.

Under a first set of assumptions called Rev 1, and summing over 8 years of data from 2008-2015, the total contribution of these federal laboratory licensors to industry gross output ranges from $23.1 billion to $76.5 billion in 2009 U.S. dollars; contributions to gross domestic product (GDP) range from $10.6 billion to $34.6 billion in 2009 U.S. dollars. Estimates of the total number of person years of employment supported range from 73,000 to 215,000 over the eight-year period.

Under a second set of assumptions called Rev 2, and summing over the same 8 years of data from 2008-2015, the total contribution of these federal laboratory licensors to industry gross output ranges from $25 billion to $83.6 billion in 2009 U.S. dollars; contributions to GDP range from $12.5 billion to $41.3 billion to in 2009 U.S. dollars. Estimates of the total number of person years of employment supported range from 86,000 to 265,000 over the eight-year period.

Background on how the I-O approach to estimating the economic impact of nonprofit licensing came to be developed is provided, along with an overview of how it has evolved since.

Obtaining better information on i) the location of the production of the royalty generating licensed products, ii) the total sales of the licensed products to the federal government which may not generate earned royalties and thus are not visible using the approach described here and on iii) the industries that characterize the licensed products, should lead to more accurate estimates, particularly when they are disaggregated by federal laboratory. It will also be helpful to account for double counting, if any, and to have either systematic weighted average royalty rate information so earned royalty income can reliably be used to estimate sales, or preferably actual cumulative product sales information.

Using the Rev 1 set of assumptions—with no attempt to normalize for research expenditures, full time technology transfer employees, character of research, the number of active license agreements, or other property of interest—the federal laboratory modeled contribution is on the order of a tenth of the Association of University Technology Managers, "AUTM", member modeled contribution over the same eight-year time period, 2008-2015.

If there is interest in using these results and this model to continue improving our national technology transfer policies and practices and to make comparisons between federal laboratories and other nonprofit licensors, such as universities, it will be necessary to standardize and harmonize the definitions of at least some of the data elements collected, to collect them over time, and to allocate resources with these goals in mind. Involvement and engagement of stakeholders in the design and implementation of the data gathering system will be key to its success.

[1] In this report, the term "federal laboratory" refers to any laboratory, any federally funded research and development center "FFRDC", or any center established under section 7 or section 9 of 15 U.S.C. § 3705 or § 3707 that is owned, leased, or otherwise used by a federal agency and funded by the federal government, whether operated by the government or by a contractor.

Introduction and background:

The benefits of research expenditures are of considerable interest to a variety of stakeholders: Funders and performers, businesses, governments, and nonprofits. Businesses must justify research expenditures to their shareholders as leading ultimately to higher productivity. Governments and nonprofits have an analogous duty to taxpayers. They want to show how their stewardship of taxpayer funded research contributes to the well being, including the economic well being, of their citizens.

Both for internal management, and also to describe the impact of technology transfer activities outside their institutions, the Association of University Technology Managers, "AUTM", has been surveying its members since 1995[2], using the AUTM Survey, a home grown survey instrument. In 1998 AUTM started systematically soliciting product commercialization narratives, now called the Better World Reports[3].

Using this information, AUTM developed various home grown approaches to describing the impact of its activities. For example, to illustrate certain societal impacts, AUTM has used the Better World Reports, tracked start-ups formed and operational, and new AUTM member licensed technologies which became available[4]. In the mid 1990's AUTM developed a home grown economic impact model which included measures of pre-production impact[5], [6] used earned royalties and an assumed royalty rate[7] to estimate licensees' sales, and Census Bureau data on salaries at technology companies to estimate jobs supported by licensing activities. These home grown economic estimates were published in the AUTM Survey in the mid and late 1990's.

The model described in this report grew out of AUTM's and the Biotechnology Innovation Organization's "BIO's", desire to move beyond home grown approaches, and to describe the economic impact of nonprofit technology transfer activities using standard economic metrics, such as gross domestic product, "GDP", gross output "GO", and employment. Consequently, in 2009, BIO commissioned David Roessner, Professor of Public Policy at the Georgia Institute of Technology, Sumiye Okubo and Mark Planting, retired economists from the Bureau of Economic Analysis "BEA", and Jennifer Bond, the former Director of the Science and Engineering Indicators Program at the NSF, to develop an economic impact model. This report, on measures of economic impact of U.S. federal laboratory licensing activity, is based on that model, first published in a 2009 report[8], and then in the peer reviewed journal Research Policy in 2013[9].

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[2] The data collected were from 1991-1995 in the first survey

[3] http://www.betterworldproject.org/

[4] See http://www.autmsurvey.org/id_2017.pdf for definitions of Start-ups, Start-ups Operational and Licensed Technologies Available.

[5] Pressman, Lori, Gutterman, Sonia K., Abrams, Irene, Geist, David E., Nelsen, Lita. 1995. "Pre-Production Investment and Jobs Induced by MIT Exclusive Patent Licenses: A Preliminary Model to Measure the Economic Impact of University Licensing", *Journal of the Association of University Technology Managers,* Volume VII: 49-82

[6] Kramer, Peter B., Scheibe, Sandy, Reavis, Donyale, and Berneman, Louis. 1997. "Induced Investments and Jobs Produced by Exclusive Patent Licenses- a Confirmatory Study", *Journal of the Association of University Technology Managers* Volume IX: 79- 97

[7] Ashley J. Stevens, presentation entitled "Measuring Economic Impact" AUTM Advanced Licensing Course, held in Arizona, December 1994

[8] "The Economic Impact of Licensed Commercialized Inventions Originating in University Research" 1996-2007, September 3, 2009, by David Roessner, Jennifer Bond, Sumiye Okubo, Mark Planting, http://www.bio.org/sites/default/files/BIO_final_report_9_3_09_rev_2_0.pdf accessed July 10, 2018

[9] David Roessner, Jennifer Bond, Sumiye Okubo, Mark Planting, "The Economic Impact of Licensed Commercialized Inventions Originating in University Research" Research Policy, May 26, 2013. 10.1016/j.respol.2012.04.015 . https://econpapers.repec.org/article/eeerespol/v_3a42_3ay_3a2013_3ai_3a1_3ap_3a23-34.htm Accessed July 10,2018

The basic concept of this model is to apply Leontief input-output, "I-O", coefficients[10] to nonprofit licensing data to estimate i) gross industry output (GO), ii) effects on GDP and iii) person-years of employment supported by nonprofit licensing activity. The I-O model follows the same underlying data framework, rules, and conventions used to measure the national economy. As noted above, the first application of the I-O model to AUTM Survey data was published in 2009, and there have been a series of published reports and calculations; in 2012[11], 2015[12], and 2017[13], based on the original concept.

The evolution of the I-O model since its first implementation in 2009 is summarized in supplementary table S-1. The 2012 report included U.S. hospitals and research institutes, "HRI's", that respond to the AUTM Survey. It also included jobs supported by the licensee's sales. The 2009 report and 2013 Research Policy paper only included jobs supported by the license income going to the university licensors.

The 2015 report used updated and increased BEA value added ratios. The 2015 update better reflected the contribution of research expenditures to the U.S. economy, including their contributions to growth and productivity similar to other capital goods[14] ,[15].

This report applies the same I-O framework to federal laboratory licensing data[16]. It provides two sets of estimates, under different assumptions, called Rev 1 and Rev 2. Rev 1 is the method used in the AUTM/BIO 2017 report, and Rev 2 is a method which changes certain assumptions as will be described in more detail in this report, and in summary form in Table A below. Rev 2 is a sensitivity analysis and a more complex model. The assumptions are probably more realistic, and the results are reassuringly similar to the simpler Rev 1.

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[10] Wassily W. Leontief "Input-Output Economics" Scientific American Vol 185. No. 4 October 1951 pp 15-21
Wassily W. Leontief "The Structure of the U.S. Economy", Scientific American Vol 212 No.4 April 1965 pp 25-35

[11] "The Economic Contribution of University/Nonprofit Inventions in the United States: 1996-2010" June 20, 2012, by Lori Pressman, David Roessner, Jennifer Bond, Sumiye Okubo, and Mark Planting, https://www.bio.org/sites/default/files/BIOEconomicImpact2012June20.pdf accessed July 10, 2018

[12] The Economic Contribution of University/Nonprofit Inventions in the United States: 1996-2013, Prepared for the Biotechnology Industry Organization March 2015 by Lori Pressman, David Roessner, Jennifer Bond, Sumiye Okubo and Mark Planting https://www.bio.org/sites/default/files/files/BIO_2015_Update_of_I-O_Eco_Imp.pdf accessed July 10, 2018

[13] The Economic Contribution of University/Nonprofit Inventions in the United States: 1996-2015, Prepared for the Biotechnology Innovation Organization and the Association of University Technology Managers by Lori Pressman, Mark Planting, Robert Yuskavage, Sumiye Okubo, Carol Moylan, and Jennifer Bond, June 2017 , accessed July 10, 2018 https://www.bio.org/sites/default/files/June%202017%20Update%20of%20I-O%20%20Economic%20Impact%20Model.pdf

[14] See R&D in the National Income and Product Accounts: A First Look at Its Effect on GDP, Barbara M. Fraumeni, Sumiye Okubo, August 2005,

[15] Measuring R&D in the National Economic Accounting System, November 2014 by Marissa J. Crawford, Jennifer Lee, John E. Jankowski, and Francisco A. Morris.

[16] Since there are only eight years of federal laboratory license income and earned royalty income data, and since the definition of federal laboratory licenses in the data as received appeared different from the definition of AUTM licenses, it was decided not to try to do the change in contribution to GDP over time analyses done in later AUTM reports, e.g. figures 3 and 4 in in the 2017 report.

Table A: Summary of key parameters in the two estimates.

	Rev 1	Rev 2
Years of federal laboratory data.	2008- 2015	2008- 2015
Base year for inflation adjusted $	2009	2009
The licensees' production occurs entirely in the U.S.	Yes	**80% domestic production**
None of the licensees' sales are final sales.	Yes	**The shares of sales to final demand are the weighted average of all of the selected manufacturing and the IT commodities to final demand. The weighted average over the 8 year period was about 50%.**
All of the intermediate inputs to production are domestic.	Yes	**Not all intermediate inputs are domestic. The domestic requirements tables are used.**
Industries of the licensees	All licensees are in a subgroup (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing."	The licensees are in a subgroup (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing." and **in industry classes 511, 514, 5415, associated with publishing, software and computer systems design and services.**

Application of the model to the federal laboratories:

Analogous legal framework:

The model was previously applied to inventions managed under the Bayh-Dole framework at universities and other hospital and research institutes that respond to the AUTM Survey. The Stevenson-Wydler framework, which applies to inventions made at federal laboratories, has a shared goal of ensuring public benefit of inventions made with federal funding. The two frameworks are analogous but not the same. Licensors generally have more leeway in licensing practices under Bayh-Dole than under Stevenson-Wydler.

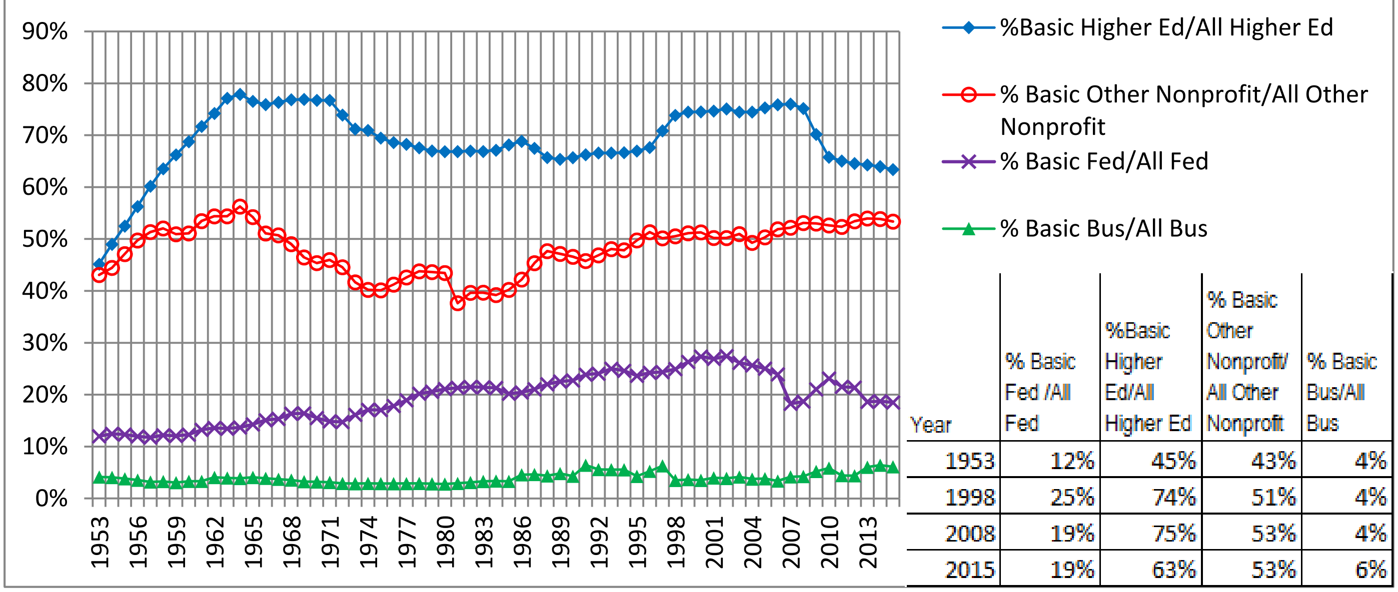
Character of Work:

As discussed in some of the earlier reports, data from HRIs that respond to the AUTM Survey were added to the model for a few reasons; evidence suggesting that the character of the work performed at such HRIs is reasonably similar to that done at universities and colleges, and that universities and HRI's sometimes share personnel[17]. Figure 1 shows that Higher

[17] For example, all investigators at the Whitehead Institute, which responds to the AUTM survey in the "HRI" category, hold joint appointments in the MIT Department of Biology. Many investigators at the Fred Hutchinson Cancer Research Center, another Hospital and Research Institute which responds to the AUTM survey hold a joint appointment at the University of Washington.

Ed[18], Other Nonprofit, and the Federal performers (including both the intramural[19] program and the Federally Funded Research and Development Centers "FFRDC's[20]") perform more Basic Research[21], as a percent of the total amount of R&D they perform, than Business does.

Figure 1: Basic R&D Expenditures *By % by Performer*: Higher Ed, Other Nonprofit, Federal, and Business.
Source Appendix Tables 4-02 and 04-03 2018 S&E Indicators



Year	% Basic Fed /All Fed	%Basic Higher Ed/All Higher Ed	% Basic Other Nonprofit/ All Other Nonprofit	% Basic Bus/All Bus
1953	12%	45%	43%	4%
1998	25%	74%	51%	4%
2008	19%	75%	53%	4%
2015	19%	63%	53%	6%

Qualitatively, the Science and Engineering "S&E" indicators produced by the National Science Foundation show that over the past few decades, about seventy percent of the research performed by the Higher Ed sector was characterized as Basic Research, about half the research performed by the Other Nonprofit sector was characterized as Basic Research, and about twenty percent of research expenditures performed by the Federal sector was characterized as Basic Research. In contrast, about five to six percent of research performed by the Business sector was characterized as Basic Research.

Federal performers perform an amount of R&D comparable to the amount performed by Higher Ed.

Over the past few decades, the amount of R&D expenditures by the Federal performers of research, including the intramural facilities and the extramural FFRDC's (about $49 billion in 2015 in 2009 dollars) is reasonably comparable the R&D expenditures by Higher Ed (about $59 billion in 2015 in 2009 dollars). See figure 2 below.

[18] The S&E indicators labeled "Universities and Colleges" "Higher Ed" starting in 2018. It is not clear if the mix of institutions changed along with the name.

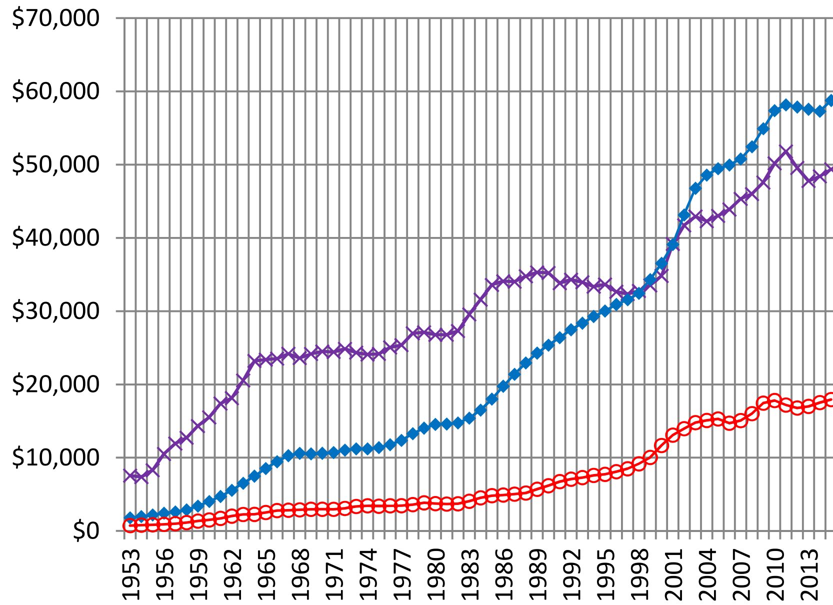
[19] Intramural performers are the agencies of the Federal Government. Their work is carried on directly by agency personnel of contractors. https://www.nsf.gov/statistics/fedfunds/glossary/def.htm

[20] FFRDC's are defined by their mission: https://www.nsf.gov/statistics/fedfunds/glossary/def.htm#extramural and listed here: https://www.nsf.gov/statistics/ffrdclist/

[21] As defined in the Science and Engineering Indicator Glossary https://www.nsf.gov/statistics/2016/nsb20161/#/report/chapter-4/glossary , and excerpted as a convenience in the Glossary and definition section at the end of this report.

Figure 2. Long Term Trends in R&D Expenditures by Nonprofit Performing Sector $ 2009 M

Source : Appendix Table 04-02 2018 S&E Indicators



Year	$M Federal	$M Higher Ed	$M Other Nonprofit
1953	7,562	1,798	736
1998	32,771	32,441	9,170
2008	45,995	52,450	16,019
2015	49,378	58,768	17,942

The S&E Indicators reports expenditures by performer, and for each performer, by source of funds. For example, within the “Higher Ed” performer, expenditures are subdivided into five categories, “Federal”, “Nonfederal government”, “Business”, “Higher Ed” and “Other Nonprofit”. Within the “Federal” category, there are two categories, “Intramural” and “FFRDC”. About two thirds of the research done by Federal performers is done at intramural facilities, i.e. by agency personnel or contractors, and a third at the FFRDC’s, i.e with some use of private sector resources. See supplementary figure S-1. Supplementary figure S-2 indicates that the character of research done at FFRDC’s is more basic than that done at intramural facilities.

FFRDC’s are a subset of the federal laboratories, defined by their mission[22]:

> “An FFRDC meets some special long-term research or development need which cannot be met as effectively by existing in-house or contractor resources. FFRDC's enable agencies to use private sector resources to accomplish tasks that are integral to the mission and operation of the sponsoring agency.”

There are more than forty FFRDC’s, sortable by various attributes, including i) three categories of Activity Type: Research and Development Laboratory, Study and Analysis Center, and Systems and Engineering Center, ii) three categories of Administrator: Industrial Firms, Nonprofit Institutions Other Than Universities and Colleges, and Universities and Colleges, Including University Consortia, and iii) twelve Sponsoring agencies.

Note that a portion of the AUTM Survey respondents’ research expenditures are received from sources other than the federal government. For example, in 2015, U.S. AUTM Survey respondents reported $65 billion total research expenditures; $39 billion from the federal government and $ 4.9 billion from industry. The balance of roughly $21 billion comes from other sources, such as internal, state, and foundation. Also “AUTM Survey respondents” may not correspond exactly to “Higher Ed” in the S&E Indicators.

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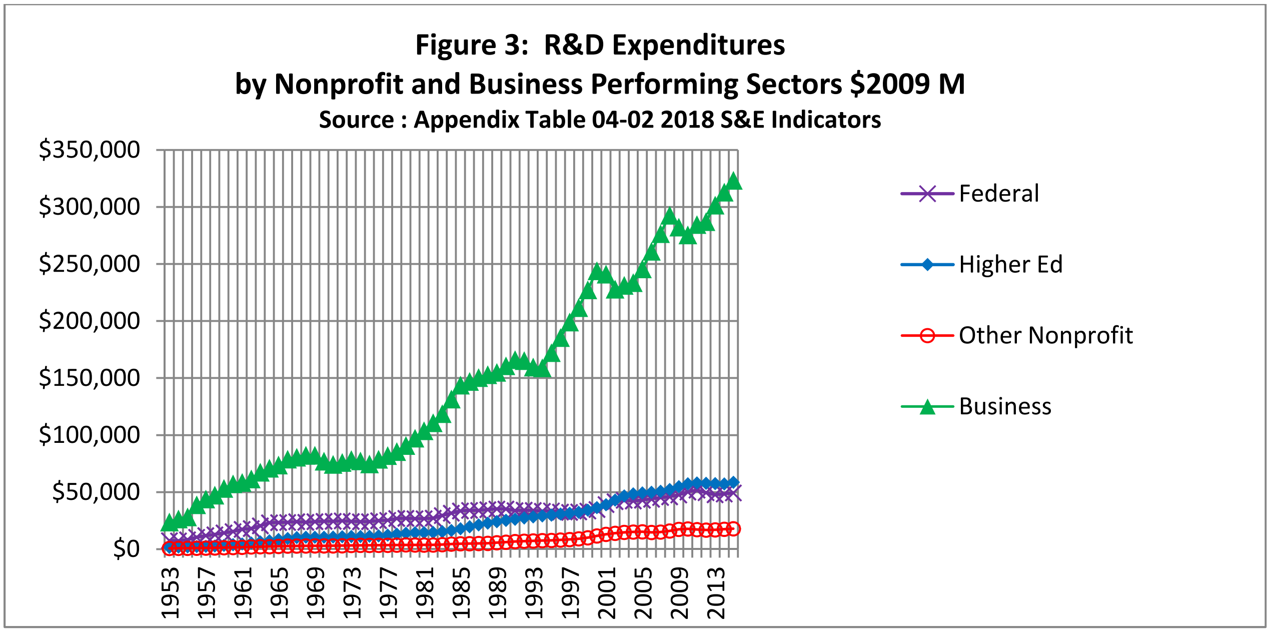
[22] https://www.nsf.gov/statistics/fedfunds/glossary/def.htm#extramural

The federal performers of research do so at a variety of facilities, including those that are both owned and operated by the federal government "GOGO's" and those that are owned by the federal government and operated by contractors "GOCO's". Of note, the GOGO's and GOCO's operate under different technology transfer frameworks, both of which differ from the Bayh-Dole framework. For example, universities generally can assert a copyright and license it, GOCO's can similarly assert a copyright and license it, and GOGO's cannot do so. University employees can consult for the private sector; government employees cannot.

Figure 3 shows long terms trends of U.S. R&D expenditures in both the profit and not for profit sectors.



As seen qualitatively in figure 3, most R&D, of all types—Basic, Applied and Development—is performed by the for profit sector. Supplementary figure S-3 illustrates that roughly seventy percent of R&D is performed by the for profit sector. Supplementary figure S-4 illustrates that most *Basic* R&D, approximately seventy to eighty percent, is performed within nonprofits, including federal laboratories. Thus nonprofits may benefit from partnering with industry in part because of their deeper pockets and emphasis on reproducibility, volume manufacturing and distribution. For profits may benefit from partnering with nonprofits in part because of their more basic research culture and emphasis on novelty. It is acceptable and even expected to invent or change a process or design specification in a research environment; it is not OK to do so in a manufacturing environment.

Brief background on economic models based on the national input-output accounts:

This section provides definitions and concepts underlying the I-O framework[23] to facilitate understanding the assumptions used when applying it to model the economic impact of federal laboratory licensing. Several paragraphs and sentences,

[23] See BEA (Bureau of Economic Analysis, U.S. Department of Commerce) BRIEFING: A Primer on BEA's Industry Accounts , accessible at http://www.bea.gov/scb/pdf/2009/06%20June/0609_indyaccts_primer_a.pdf : By Mary L. Streitwieser "Concepts and Methods of the Input-Output Accounts," accessible at http://www.bea.gov/papers/pdf/IOmanual_092906.pdf : By Karen J. Horowitz and Mark A. Planting. Chapter 12 discusses Input-Output modeling and applications.

but not all paragraphs and sentences, in this section are taken verbatim from the above noted references. As always, the primary source is the preferred reference.

The terms “input” and “output,” but not “cost” and “revenue” are apt, as the same economic transaction is “output” to one party, the seller, and “input” to the other, the buyer. When the buyer is the last buyer, they are the “final user” in I-O parlance. The sum of all purchases by “final users” is “final demand.” When the buyer uses that input to produce its own, or his or her own, output, then such input is called “intermediate input.” Output multipliers can only be applied to final demand.

The word “commodity” in BEA explanatory material aligns with its use in economics as any marketable item, whether goods or services, which is the subject of a transaction. The everyday meaning of “commodity” means goods which are supplied without differentiation such as salt or copper. Thus, it is useful to keep in mind the economic meaning, not the everyday meaning, of “commodity” while reading about I-O models.

The largest single source of U.S. I-O data is the Economic Census, which is conducted once every 5 years by the U.S. Bureau of the Census. The models start with two basic tables, the “make” and “use” table. A make table shows the value of each I-O commodity produced by each industry in a given year. Before such tables can be produced, classifications are needed for “commodities” and “industries.”

For the I-O accounts, BEA uses a classification system that is based on the North American Industry Classification System (NAICS). The I-O classification system is consistent with that used by the principal agencies that provide the source data used in the I-O accounts and by the preparers of the national accounts and other economic series that are used for analysis in conjunction with the I-O accounts. In I-O accounting, each industry is associated with a commodity that is considered the primary product of that industry. The 20 major industry classes and their two-digit NAICS codes are found in supplementary table S-2.

The coefficients used in this report assume that activity of federal laboratory licensors is similar to industry class 61 “Educational Services”. Rev 1 assumes that the outputs of the technology licensees are in a subgroup of industry classes 31-33 “Manufacturing.” The subgroups are: chemical products (325), plastics and rubber products (326), nonmetallic mineral products, (327), fabricated metal products (332), machinery (333), computer and electronic products (334), electrical equipment appliances and components (335), other transportation equipment (3364OT), and miscellaneous manufacturing (339). Rev 2 assumes that the outputs of the technologies licensees are in manufacturing, as above, and also in industry classes 511, 514, and 5415, associated with publishing, software and computer systems design and services.

The use table shows the uses of commodities by industries as intermediate inputs and by final users. “Use of commodities by industries as intermediate inputs,” is roughly analogous, for manufacturers, to cost of goods sold (COGS) in financial statements[24], and the “use by final users” would be understood in everyday parlance as the sum of purchases by persons and by government, business investment, and exports less imports.[25] For the economy as a whole, the total of all final uses of commodities equals the sum of all value added by all industries, or GDP.

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[24] The analogy fails for wholesalers and retailers in the I-O accounts, where “intermediate input” is equivalent to the cost of running the retail or wholesale operation excluding labor.

[25] The word “investment” is used in a manufacturing context, not a financial one, and refers to investment in new fixed assets or inventories, or for replacing depreciated fixed assets. It does not mean venture investment or stock purchases. Imports are used in the United States but produced abroad.

Table B from the BEA Primer is copied below to illustrate that some observations are consistent with intuition or at least not intuitively surprising. First, it supports the often-heard truism that “The U.S. is a service economy,” as more of the GDP is characterized as “service” than as “manufacturing”. That individuals directly consumed more services ($7.9 trillion) than manufactured goods ($1.7 trillion) in 2007 is another unsurprising observation. The single largest intermediate input to service industries is services (5,030,294 ÷ 6,373,425 = 79%) and the single largest intermediate input to manufacturing industries is manufactured commodities (1,609,532 ÷ 3,417,099 = 47%).

Table B. The Use of Commodities by Industries, 2007 [Millions of dollars]

Commodities/industries	Agriculture, mining, and construction[1]	Manufacturing		Services[2]	Government[3]	**Total intermediate use**	Personal consumption expenditures	Private fixed investment	Change in private inventories[4]	Net trade	Government consumption expenditures and gross investment[3]	Total final uses (GDP)	**Total commodity output**
		Total	Computer and electronic products										
Agriculture, mining, and construction[1]	154,402	595,776	944	248,419	89,143	**1,087,739**	59,605	1,011,206	11,099	–271,109	293,340	1,104,141	**2,191,880**
Manufacturing	415,614	1,609,532	105,397	929,547	317,079	**3,271,773**	1,681,597	689,338	34,532	–779,107	114,238	1,740,597	**5,012,370**
Computer and electronic products	4,401	108,822	66,881	79,778	26,520	**219,521**	73,990	186,349	2,938	–148,523	40,576	155,331	**374,852**
Services[2]	464,515	1,135,150	123,225	5,030,294	720,891	**7,350,850**	7,904,854	527,305	10,205	441,528	53,167	8,937,059	**16,287,909**
Government[3]	1,579	3,170	269	69,801	9,904	**84,454**	63,599	...	...	314	2,214,174	2,278,087	**2,362,541**
Total intermediate inputs[5]	**1,038,805**	**3,417,099**	**241,727**	**6,374,425**	**1,171,034**	**12,001,363**	...	...	...	...	...	...	...
Compensation of employees	549,340	969,412	139,114	4,823,282	1,477,338	**7,819,371**	...	...	...	...	...	...	...
Taxes on production and imports less subsidies	28,529	57,178	4,483	893,320	–15,874	**963,153**	...	...	...	...	...	...	...
Gross operating surplus	475,893	590,236	2,697	3,677,424	281,462	**5,025,015**	...	...	...	...	...	...	...
Total value added	**1,053,761**	**1,616,826**	**146,294**	**9,394,025**	**1,742,926**	...	...	...	...	...	...	**13,807,538**	...
Total industry output	**2,092,567**	**5,033,925**	**388,021**	**15,768,450**	**2,913,960**	...	**9,710,168**	**2,133,993**	**–3,642**	**–707,810**	**2,674,830**	...	**25,808,901**

1. Agriculture consists of agriculture, forestry, fishing and hunting.
2. Consists of utilities; wholesale trade; retail trade; transportation and warehousing; information; finance, insurance, real estate, rental, and leasing; professional and business services; educational services, health care, and social assistance; arts, entertainment, recreation, accommodation, and food services; and other services, except government.
3. Consists of federal, state, and local governments.
4. Includes inventory valuation adjustment.
5. Includes noncomparable imports; inventory valuation adjustment; rest-of-the-world, and scrap, used and secondhand goods.

Note that “total value added” is a measure of the value of factors of production – in textbook economics, land, labor and capital. It is not the same as profit. It includes compensation of employees, taxes on production and imports minus subsidies, and gross operating surplus. This surplus can be used, in the case of industries, to build more capacity, to pay shareholders or owners, for income taxes, or for their own R&D. By definition, this study assumes that all federal laboratory license income contributes to GDP through its use to fund operating expenses. This is the same assumption that was used in the prior studies of university/nonprofit licensing. This study assumes that *no* license income received by the federal laboratories is paid directly to the U.S. Treasury, in which case it would be treated differently. As with the nonprofits in the prior studies, the output of general government units such as federal laboratories is measured as total expenses. Within the national accounts, the output of federal laboratories is treated as government consumption and thus is part of GDP.

Four “requirements” tables are derived from the make and use tables. These are used to relate final demand to gross output. If final demand is known, for example, or there is a change in final demand, then the requirements tables can be used to show the inputs required by an industry to produce a given output. When only the direct requirements are considered (the inputs needed to produce the inputs are not included), the table is called a “direct requirement” table. When all inputs needed to make the inputs are considered, then the table is called the “total requirements table.” The total requirements table accounts for all interactions required by industries to support a given level of final demand. Note that output multipliers can only be used when final demand is known.

The total requirements table is used in conjunction with employment by industry and value added by industry to derive multipliers that related final demand sales to changes in economy wide employment and value added (GDP). Additionally, estimates of commodity imports by industry can be combined with the use and make tables to derive a domestic total requirements table that relates final demand sales to domestic production, employment and value added. In the I-O accounts non-profit output is all sold to final demand. Thus, an output multiplier *is* applied to license income received by the federal laboratories, since all of their output is consumed by final demand. In Rev 1 all sales of licensees are assumed to be sold to other intermediate industries and it is therefore not appropriate to apply multipliers. In Rev 2, the share of sales to final demand is based on industry (the manufacturing and IT industry classes noted previously) specific patterns, and an output multiplier is applied to this share of sales.

Rev 1 assumptions:

General:
i) The FL licensors will be treated as though in industry class “61,” educational services, and their licensees are in a subgroup[26] of industry classes 31-33: “Manufacturing.”
ii) The value-added ratio, the output multiplier, and the employment to output ratio are all applied to current dollars. GDP and gross output are then normalized to 2009 dollars.
iii) Sales of the licensee’s products are estimated using the reported earned royalty income “ERI” (earned royalties on product sales) divided by an assumed royalty rate.
iv) The relevant sales are captured by the royalty base.

For the GDP calculation:
i) 100% of FL expenditures contribute to GDP.
ii) 100% of licensee’s sales are produced domestically.

For the gross output calculation:
i) The license income received by federal laboratory licensors is all spent in the U.S., and is treated as final demand. The effect of this revenue on gross output is increased by one iteration of purchases of intermediate inputs, so called “direct requirements,” plus the output required by all other industries to produce inputs to federal laboratories, the “indirect requirements”.
ii) 100% of licensees’ sales are by domestic producers and 100% of the intermediate inputs for this production are also domestic.
iii) Since the fraction of the licensee’s sales that are final sales is unknown, no output multipliers are applied. Gross output is simply total licensees’ sales.

[26] The subgroups are: chemical products, plastics and rubber, nonmetallic minerals, fabricated metals, computer and electronics, electrical equipment, transportation equipment, miscellaneous manufacturing and machinery

The economic impact model using license income data and I-O coefficients: Rev 1

GDP:

A: A portion associated with the license income received by the FL licensors	+	**B:** A portion associated with licensed product sales by the licensees

A_{GDP} = (license income received in 2009 dollars) = (license income received)[27] / (price index for GDP, index numbers, 2009 =1.00)[28]

B_{GDP} = ((modeled sales by licensees[29]) x (value-added ratio from U.S. I-O tables)) / (price index for GDP, index numbers, 2009 =1.00)

Gross industry output:

A: A portion associated with the license income received by the FL licensors	+	**B:** A portion associated with licensed product sales by the licensees

A_{GO} is made up of two parts, and = $A1_{go}$ + $A2_{go}$
$A1_{GO}$: the effect of the license income received by the FL licensors, and $A2_{go}$: the effect outside the licensor when the licensor spends that income.

$A1_{GO}$ = (license income received) / (price index for GDP, index numbers, 2009 =1.00)
$A2_{GO}$ = ((license income received in current U.S. dollars) × (NAICS 61 output multiplier from U.S. I-O tables)[30]) / price index for GDP, index numbers, 2009 =1.00)

B_{GO} = ((modeled sales by licensees[31]) / (price index for GDP, index numbers, 2009 =1.00)

Employment supported by final purchases associated with federal laboratory licensing:

A: A portion associated with the license income received by the FL licensors	+	**B:** A portion associated with licensed product sales by the licensees

A_{YES} = (employment multiplier for FL licensors) x (current license income received)

B_{YES} = (employment multiplier for manufacturing companies) x (modeled sales by licensees)

[27] Total license income received (as reported).
[28] The multipliers are applied to current dollar license income and current dollar modeled sales. The result is adjusted to 2009 U.S.dollars
[29] ((Earned Royalty Income "ERI" in current dollars) ÷ (royalty rate))
[30] See Appendix B
[31] ((Earned Royalty Income "ERI" in current dollars) ÷ (royalty rate))

Comments on assumptions and caveats on accuracy of estimates: Rev 1

Rev 1 assumes that all of the licensees'sales are commodities produced by domestic producers, and that all intermediate inputs are also domestically produced. These assumptions, in isolation, lead to overestimates; some production may take place overseas and some of the inputs into the production may be imported.

Rev 1 assumes that all sales result from manufacturing activity. To the extent that some important federal laboratory licensees are in computer and information technology, this assumption in isolation leads to an underestimate, as value-added ratios are higher in these industries.

Rev 1 assumes that none of the licensees' sales are final sales, which leads to an underestimate.

Licensed products are not expected to generate earned royalties when sold to the U.S. government. This model would not capture such sales, and their absence leads to an underestimate. It appears that the DoD gathered information[32] on such presumed non royalty bearing military sales. To the extent that the federal laboratories, the DoD and others, know the amount of non royalty bearing sales to the U.S. Government, these could be added to the total product sales.

Not all licenses contain earned royalty terms. The license exhibit Google filed with its S-1, for example, contains an equity provision for Stanford, but no apparent earned royalty. This phenomenon means that using the method of calculating product sales via dividing earned royalty income by an average weighted royalty rate may underestimate total licensees' sales. Some licenses contain royalties on products, but not on services. [33] Royalty offsets and combination product language[34] through reducing the royalty base, contribute to an effective royalty rate lower than the one apparently specified in the license contract. These factors suggest that estimating licensees' sales by using (ERI as reported) ÷ (an assumed royalty rate) may underestimate licensees' sales, and thus GDP, gross output, and employment.

Synagis is highlighted on the NIH OTT website, in DoD reports, and on the web page of the USUHS technology transfer office. The DoD report indicates that this single product accounted for roughly $14.1B in sales from 2000-2014. It is important to adjust for double counting, if any, between federal laboratories which could lead to an overestimate for the federal laboratories as a whole.

There is some overlap between AUTM and FFRDC data because some of the administrators of FFRDC's are universities. For example, the University of Iowa is the administrator for Ames Laboratory, MIT for Lincoln Laboratory, the University of California for Lawrence Berkeley National Laboratory, Caltech for JPL. Thus, double counting may also be occurring between federal laboratories and university administered FFRDC's.

It has been suggested that an assumed product substitution rate should be used to reduce overall estimates. There is not sufficient information to estimate substitution, but to the extent that substitution maintains or increases U.S. domestic production, or use of U.S. intermediate inputs, then it is not a subtraction.

Companies highlight their new products, and sometimes they depend on such "substitution" to ensure growth. Frederick J. Palensky, 3M's chief technology officer, was interviewed in the January 9, 2012 Chemical & Engineering News: "New

[32] See for example pages 12-13 of National Economic Impacts from DoD License Agreements With U.S. Industry 2000-2014 https://techlinkcenter.org/wp-content/uploads/2017/01/2016-DoD-Licensing-Study-E-Publication.pdf accessed July 10, 2018

[33] http://www.sec.gov/Archives/edgar/data/1110803/0001012870-00-001863.txt accessed July 10, 2018

[34] https://www.sec.gov/Archives/edgar/data/1424740/000095013508002207/b68098btexv10w1.htm accessed July 10, 2018

products—five years old or less—accounted for 31% of sales in 2010, and when 2011's new products are included in the tally, they are likely to account for 33% of sales," Palensky says. "3M's goal is for new products to reach 40% of sales. The company's businesses won't grow at all if new product sales don't reach at least 25%," he says, "so a high-functioning R&D organization is critical for survival."

Since economies grow through renewal and replacement, to assure growth, renewal and replacement must exceed loss. Thus, the caveat on product substitution is written as assuming "no detrimental product substitution effects."

Rev 2 assumptions:

General:

i) The FL licensors will be treated as though in industry class "61," educational services, and their licensees are in two subgroups of manufacturing industry classes 31-33:, and also classes 511, 514, 5415, associated with publishing, software and computer systems design and services.
ii) The value-added ratio, the output multiplier, and the employment to output ratio are all applied to current dollars. GDP and gross output are then normalized to 2009 dollars.
iii) Sales of the licensees' products are estimated using the reported earned royalty income, "ERI", (earned royalties on product sales) divided by an assumed royalty rate.
iv) The relevant sales are captured by the royalty base.

For the GDP calculation:

i) 100% of FL expenditures contribute to GDP.
ii) 80% of licensee's sales are produced domestically.

For the gross output calculation:

i) The license income received by federal laboratory licensors is all part of U.S. output. To account for imports to industries supplying federal laboratories, the domestic requirements multiplier is applied to federal laboratory license income to obtain the total output changes of all industries because of the spending of the federal laboratories. The effect of this revenue on gross output of all industries after adjusting for imports, is to increase the production of other industries.
ii) 80% of licensee's sales are produced domestically and the domestic requirement tables are used to exclude the impact of imported intermediate inputs.
iii) Approximately 50% of the licensees' sales are to final demand (the specific share varies slightly each year based on the data from the annual input-output accounts).

The economic impact model using license income data and I-O coefficients: Rev 2

GDP:

A: A portion associated with the license income received by the FL licensors	+	B: A portion associated with licensed product sales by the licensees

A_{GDP} = (license income received in 2009 dollars) = (license income received)[35] / (price index for GDP, index numbers, 2009 =1.00)[36]

[35] Total license income received (as reported).

B_{GDP} = ((modeled domestically produced sales by licensees[37]) x (value-added ratio from U.S. I-O tables)) / (price index for GDP, index numbers, 2009 =1.00) + (an additional share of domestically produced sales attributable to final demand) x (domestic value added multiplier) / (price index for GDP, index numbers, 2009 =1.00)

<u>Gross industry output:</u>

A: A portion associated with the license income received by the FL licensors	+	B: A portion associated with licensed product sales by the licensees

A_{GO} is made up of two parts, and = $A1_{go}$ + $A2_{go}$
$A1_{GO}$: the effect of the license income received by the FL licensors, and $A2_{go}$: the effect outside the licensor when the licensor spends that income.

$A1_{GO}$ = (license income received) / (price index for GDP, index numbers, 2009 =1.00)
$A2_{GO}$ = ((license income received) × (domestic NAICS 61 output multiplier from U.S. I-O tables)[38]) / price index for GDP, index numbers, 2009 =1.00)

B_{GO} = [(modeled domestically produced sales by licensees[39]) + (the additional share of domestically produced sales attributable to domestic final demand)] x (domestic output multiplier)

<u>Employment supported by final purchases associated with federal laboratory licensing:</u>

A: A portion associated with the license income received by FL licensors	+	B: A portion associated with licensed product sales by the licensees

A_{YES} = (domestic employment multiplier for FL licensors) x (current license income received)

B_{YES} = [(modeled domestically produced sales by licensees) x (ratio of employment to output for manufacturing and IT companies]

+[(the additional share of domestically produced sales attributable to final demand) x (domestic employment multiplier for manufacturing and IT companies))]

Comments on assumptions and caveats on accuracy of estimates: Rev 2

Rev 2 uses a domestic production factor of .80, that is 80% of licensed production takes place within the U.S. In this time of global production and supply chains, it seems unrealistic to assume 100% domestic production. Factors considered leading to this estimate pending more actual data include:

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[36] The multipliers are applied to current dollar license income and current dollar modeled sales. The result is adjusted to 2009 U.S.dollars.
[37] ((Earned Royalty Income "ERI" as reported) ÷ (royalty rate)) x .8
[38] See Appendix C
[39] ((ERI as reported) ÷ (royalty rate)) x .8

There are known patterns of production outside the U.S. "OUS" by NAICS code for firms with more than 500 employees. The DoD provided information[40] on the percent of actual sales by large companies: "However, because of the previously mentioned top-selling drug, the large corporation category accounted for 82 percent of the total sales related to the DoD license agreements. If this product is excluded, the large corporation percentage drops to 41 percent, with small businesses accounting for 59 percent of the total sales.

AUTM has data on the size of their licensees at the time the licenses or option agreements are signed, not at the time earned royalties are received[41]. A domestic production factor was derived for AUTM member licensees assuming half were large entities at the time the royalties were received. For AUTM, this hypothetical domestic production factor was .86 in 1998, .81 in 2008 and .77 in 2015. Note that using the percentage of large company licensees will understate the share of large company licensed product *sales* since average sales per firm are higher for large firms than small firms.

Thus, the selection of .8, which, in isolation would lower the Rev 2 estimate relative to Rev 1.

Rev 2 assumes that all sales result both from manufacturing and IT related activity. This assumption increases the Rev 2 estimate relative to Rev 1.

Rev 2 assumes that some of licensees' sales are sales to final demand. This assumption increases the Rev 2 estimates relative to Rev 1.

As noted previously in the section on Rev 1[42], sales to the U.S. government do not generate earned royalties, and thus are invisible to both Rev 1 and Rev 2. And as for Rev 1, not all commercial licenses contain earned royalty terms. These factors, in isolation, lead to underestimates of impact.

Inference on a federal laboratory royalty rate:

The royalty rate, combined with the reported earned royalty income, "ERI", is an important input to the model. Exhibit A shows the basis of inferring a weighted average royalty rate for 2009-2014 NIH OTT license data of 1.37%.

This is reasonably consistent with available AUTM data on average earned royalty rates. The AUTM survey reported an average royalty rate of 1.7% in FY2011 and 1.8% in FY2012.[43] These rates were calculated by asking respondents to report the product sales their licensees provided in royalty reports to AUTM member licensors and the earned royalties AUTM members received[44]:

[40] Page 14 of National Economic Impacts from DoD License Agreements with U.S. Industry 2000-2014 https://techlinkcenter.org/wp-content/uploads/2017/01/2016-DoD-Licensing-Study-E-Publication.pdf accessed July 10, 2018

[41] Between 1996 and 2015 sixty to seventy percent were either small companies or start-ups. Starting in 2004, AUTM tracked licenses and options separately. Previously, they were counted together. Between 2004-2015, 16-21% of the Licenses/options were options.

[42] See for example pages 12 -13 of National Economic Impacts from DoD License Agreements With U.S. Industry

[43] Page 40 FY2012 AUTM Survey

[44] These data apply to the subset of all AUTM Survey respondents, including patent management firms and Canadian respondents, not only U.S. universities and U.S. hospitals and research institutes that responded to the question on their licensees' net sales. In 2011, there were 9113 licenses generating running royalties of $1.429 B. In 2012, there were 9613 licenses generating running royalties of $1.961B.

> "Further, these organizations said that 3,014 licensees reported $36.8 billion in sales, implying average sales of $12.2 million per license and paid $657.7 million in royalties, implying an average royalty rate of 1.8 percent. In contrast, FY2011 data indicated that 2,281 licensees achieved $36.9 billion in product sales, implying average sales of $16.2 million per license, and paid $661.6 million in royalties, implying an average royalty rate of 1.7 percent."

It is not uncommon to see high rates in surveys of royalty rates. The above noted average royalty rate numbers from AUTM, and Exhibit A may be consistent with some apparently higher public numbers when combined with royalty offsets and debundling provisions often found in license agreements, examples of which can be found in template license agreements and in numerically, but not structurally, redacted SEC filings[45].

Comments on the data used as input to the model:

Federal laboratory data:

The federal laboratory data are currently in flux. Supplementary table S-3 shows the data as received from NIST November 2017[46]. Supplementary table S-4 shows the data as adjusted for this report. Additional data and corrections to the data have since become available. Supplementary table S-4 uses the HHS data found on the NIH OTT website, shown in pink. A placeholder value was added for DOD ERI for 2008, VA ERI for 2008, and DOI ERI for 2010. A place holder for License Income was added for the VA for 2012. Placeholder data are in yellow. Using the data on the HHS website reduce the modeled impact. The placeholder edits increase the modeled impact. The adjusted totals are similar to the totals as received.

Note that Earned Royalty Income is by definition a subset of License Income, and for many labs reporting this is not the case. There are some instances where ERI was larger than License Income (HHS data as received), and many where it is equal to total License Income. ERI being equal to License Income is plausible but improbable as this would mean that the licenses have no upfront fees, annual payments, or milestone payments. Most of the impact of the model derives from the licensees' product sales, so this is potentially a significant source of inaccuracy. See impact multipliers per million dollars of Earned Royalty Income in Tables C and D and per million dollars of License Income in Table E below.

Table C: Rev 1 Impact multipliers per $1M of ERI only, weighted average for 8 years of FL and BEA coefficients

	1.4% royalty rate	2% royalty rate	5% royalty rate
$M GDP from ERI only per $M of ERI	32	22	9
Employment from ERI only per $M ERI	191	134	54
$M GO from ERI only per $M ERI	71	50	20

Table D. Rev 1 Impact multipliers per $1M of ERI : 2015 BEA coefficients only

	1.4% royalty rate	2% royalty rate	5% royalty rate
$M GDP from ERI only per $M of ERI	33	23	9
Employment from ERI only per $M ERI	174	122	49
$M GO from ERI only per $M ERI	71	50	20

Comments and observations on Table D in comparison with Table C:

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45 https://www.sec.gov/Archives/edgar/data/1110803/0001012870-00-001863.txt, accessed July 10, 2018

46 There was a cell programming error in the data as received; the TOTAL ERI did not include DOD ERI for FY 2009.

The value added ratios have drifted up – presumably in part due to increased efficiencies, and the jobs/output multipliers in the manufacturing sector have drifted down, due to the same presumed increase in efficiency. Recall that Rev 1 of the model applied no multipliers to gross output, so that gross output per dollar of earned royalty income is unchanged by considering only a single year.

Table E shows the multipliers for the License Income portion. The different royalty rates are included to make the points that i) this contribution is of course *independent* of royalty rate, and ii) as a percentage of the total, increases if the assumed royalty rate is higher.

Table E: Rev 1 Impact multipliers based on License Income alone, 2015 BEA coefficients only.

	1.4% royalty rate	2% royalty rate	5% royalty rate
$M GDP from License Income only per $M of License Income	1	1	1
Employment from License Income only per $M of License Income	11	11	11
$M GO from License Income only per $M ERI of License Income	1.72	1.72	1.72

The highest impact occurs if all or most of the License Income comes from Earned Royalty Income. See the bolded rows in the supplementary table S-5. The weighted average percent of License Income which is comprised of Earned Royalty Income, as reported and as amended for the 8 years of available data is 81% and 77% respectively, suggesting that top rows of supplementary table S-5 are the most relevant and that Tables C and D are good approximations, providing there are good earned royalty data.

Most of the federal laboratory income, License Income and Earned Royalty Income, derives from the HHS and DOE. The HHS figures, as amended, and the DOE figures as received are consistent with ERI being less than total License Income.

Since there is interest in comparing this data with AUTM data, "License Income", and not "Invention License Income" was used. Invention License Income appears to be intended to capture income associated primarily with patent licenses. The AUTM definitions of reportable licenses and license income are in the Glossary of this report and include licenses to types of intellectual property other than patents.

Federal data and collaborations with regard to data definition and collection:

The definitions and demarcations of the industry accounts needed to calculate the multipliers in Appendices B and C of this report started at least as early as 1941.[47] The U.S. data on research expenditures and performers began to be gathered in the early 1950's.

> "In 1953, NSF established the Survey of Federal Funds for Research and Development, which collects data on R&D obligations made by federal agencies. NSF also began to collect data on R&D performance in 1953 when it funded the first Survey of Industrial Research and Development. The Bureau of Labor Statistics (BLS) fielded the first Industrial R&D Survey for NSF; administration of the survey was later transferred to the U.S. Census Bureau."[48]

[47] Martin C. Kohli, "Leontief and the U.S. Bureau of Labor Statistics, 1941–54: Developing a Framework for Measurement" ,History of Political Economy Annual Supplement to Volume 33 (2001) 190-212

[48] Measuring the Science and Engineering Enterprise: Priorities for the Division of Science Resources Studies, 2000, page 23, National Academies Press, Washington DC.

In 2004, the National Academies' Committee on National Statistics recommended the redesign of the Survey of Industrial Research and Development. After this review, the Census Bureau and the NSF collaborated to understand what type of data was now needed and the availability of data. They solicited input from data providers, including company executives, and from data users, including the BEA. As a result, the Census Bureau broke the new survey into four parts so that each part could be sent to the most appropriate responders in a company.

The result of this thorough effort was the replacement in 2010 of the Survey of Industrial Research and Development with the new Business R&D and Innovation Survey, "BRDIS". In 2015, over forty thousand companies received the BRDIS survey; nearly eighty percent responded. BRDIS data enabled the change in treatment of R&D in the national accounts, which increased the value-added ratios used to estimate GDP in this model.

Federal laboratory I-O coefficients and results:

The FL data and Rev 1 and Rev 2 I-O coefficients are in Appendices B and C. The GDP, employment and gross output calculations for the federal laboratories Rev 1 and Rev 2 are in Appendices D and E, respectively.

Since the royalty rate is clearly a key input, the calculations were run for three assumed royalties; 1.4% and 2% and 5%.

Summing over 8 years of data for the federal laboratories, assuming no detrimental product substitution effects, and all the Rev 1 assumptions, then for royalty rates ranging from 1.4% to 5%, and due to the fact that the impacts are inversely proportional to the estimated weighted average royalty rate, an estimate for the total contribution of federal laboratory licensing to gross industry output ranges from $76.5 to $23.1 billion in 2009 U.S. dollars; and contributions to GDP range from $34.6 to $10.6 billion in 2009 U.S. dollars. Estimates of the total number of person years of employment supported by U.S. federal laboratories licensees' product sales range from 215,000 to 73,000 over the eight year period.

Summing over 8 years of data for the federal laboratories, assuming no detrimental product substitution effects, and all the Rev 2 assumptions, then for royalty rates ranging from 1.4% to 5%, and due to the fact that the impacts are inversely proportional to the estimated weighted average royalty rate, an estimate for the total contribution of federal laboratory licensing to gross industry output ranges $83.6 to $25 billion in 2009 U.S. dollars; and contributions to GDP range from $41.3 billion to $12.5 billion in 2009 U.S. dollars. Estimates of the total number of person years of employment supported by U.S. federal laboratories licensees' product sales range from 265,000 to 86,000 over the eight year period.

Empirical evidence on weighted average royalty rates, 1.7% and 1.8% for AUTM Survey respondents, and the apparent 1.4% weighted average earned royalty income derivable from public NIH information, supports estimates at the higher end of the range.

Rev 2 is a more complex and probably more realistic model. It is unlikely that all production is domestic in a global economy, as was the assumption in Rev 1. It is unlikely that all products are manufactured parts when software and data are essential tools of our modern economy, as had been the assumption in Rev 1. And it is similarly unlikely that no sales go to final demand, -again, as had been the assumption in Rev 1. So it is reassuring to see both good agreement, and the expected differences between the two. More accurate and complete data will further enhance the usefulness of this approach.

Obtaining better information on i) the location of the production of the licensed products, ii) the total sales of the licensed products to the federal government which may not generate earned royalties and thus are not visible using the approach described here and on iii) the industries which characterize the licensed products should lead to more accurate estimates, particularly when they are disaggregated by federal laboratory. Some information on the location of the production of licensed products could be estimated from the sizes of the licensees, preferably the sizes of the licensees at the time the sales are made. However, this will underestimate the sales of the larger firms. It will also be helpful to account for double counting, if any, and to have either systematic weighted average royalty rate information so earned royalty income can reliably be used to estimate sales, or actual cumulative product sales information.

Comparisons and caveats:

Appendix F shows I-O modeled contributions to GDP, GO and employment for AUTM members[49] and for federal laboratories between 2008-2015. The modeled AUTM member contribution is roughly ten times the modeled FL contribution over the same eight year time period. No attempts have been made to normalize to research expenditures, FTE's employed in technology transfer, character of research, the number of active license agreements, or other property of interest. These estimates result from payments from license agreements between companies and nonprofits in which the company agrees to pay the nonprofit for the use of technology created by the nonprofit. There may be fruitful interactions between companies and nonprofits which do not result in license payments, or which are not documented, or both. This model does not attribute a value to Cooperative Research and Development Agreements, "CRDA's", which do not result in an income generating license agreement between the federal laboratory and the CRDA partner.

The economic impact of licensing activity is a subset of the impact of research as a whole. In 1962, motivated to find and characterize approaches to increasing U.S. economic growth, Denison described methods for teasing apart contributions to increases in productivity including a contribution attributable to "the advance of knowledge".

> "..it is clear that economic growth, occurring within the general institutional setting of a democratic, largely free-enterprise society, has stemmed and will stem mainly from an increased labor force, more education, more capital, and the advance of knowledge, …."[50]

Denison was able to impute value to "the advance of knowledge" because scaling effects were insufficient to explain the growth in productivity he observed from analyzing the data available to him at the time. It may be that it's what you can't count that counts, but much is learned by counting.

Other potential data of interest:

Other data of interest include timelines[51], which may shed light on product development times. How much time elapses from patent filing to license to first earned royalty, from conception to first sale, from lab to market? Do most licenses end before or after the patents expire, and does this vary by technical field? Dates are often stored in technology transfer office databases, and these timelines could provide additional significant metrics, perhaps with modest effort. The fraction of technologies commercialized is also of interest, and could perhaps be looked at once there are reasonably comparable data on licensing of intellectual property "IP" characterized by the nature of the IP, including: patents, copyright, data, know-how, biological materials.

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[49] The AUTM data used are the last 8 years of data in the June 2017 report. The price index deflators used are slightly different from the ones used here, as the deflators are updated from time to time.

[50] Denison, Edward F. in "United States Economic Growth" p 117. He used data from 1909-1957.

[51] See figures 4, 6A and 6B of Pressman 2012, "DNA Patent Licensing Under Two Policy Frameworks: "*Implications for Patient Access to Clinical Diagnostic Genomic Tests and Licensing Practice in the Not-For-Profit Sector"* Life Sciences Law & Industry Report (March) https://www.uspto.gov/sites/default/files/aia_implementation/gene-comment-pressman.pdf accessed July 10,2018

Connectivity maps, or Pajek diagrams are also of interest, and have been used by Woody Powell and others to document the growth and value of interorganizational innovation clusters, including connections between for profits and nonprofits[52]. Their work suggests that organizational diversity drives innovation, at least in biotechnology:

> "Neither money nor market power, or the sheer force of novel ideas dominates the field. Rather, those organizations with diverse portfolios of well connected collaborators are found in the most cohesive, central positions and have the largest hand in shaping the evolution of the field."

Their approach could place value on the existence of collaborations which do not necessarily generate earned license revenue. The output would be visualizations of connections, which become denser and more diverse with time.

Collections of product commercialization narratives, preferably curated and searchable by technology commercialized, intellectual property licensed or transferred, timelines and commercial outcomes, to the extent the later are reportable, and other properties of interest, may also shed light on the workings of the nonprofit innovation ecosystem. AUTM has now collected over 500 such narratives, to date, curated only by the state of the licensor. Federal laboratory technology transfer reports often contain such narratives which could potentially be curated, coded, studied and perhaps aggregated and abstracted in such a way as to fully preserve confidentiality while revealing actionable insights.

Discussion:

In the context of NIST's ROI initiative, a model previously used to measure the economic impact of AUTM member technology transfer activities was applied to federal laboratory technology transfer data. Universities and federal laboratories have a shared interest in enabling and increasing public benefit from the research they do.

They also are different in many respects. They have different missions and technology transfer policies and regulatory frameworks. The mix of basic and applied research is different. Federal laboratories do more defense related research than AUTM members do[53]. AUTM and AUTM members developed a home grown system for looking at the outcome of AUTM member technology transfer activity and have been gathering data for more than twenty-five years. The federal laboratories, perhaps in part because of their variety of activities, administrators and sponsors, have not yet developed a similar framework. The most recent application of the I-O model to AUTM data covered the period from 1996-2015. This first application of the I-O model to federal laboratory technology transfer activities covers data from 2008-2015.

Using the same set of assumptions, called Rev 1, —with no attempt to normalize for research expenditures, full time technology transfer employees, character of research, the number of active license agreements, or other property of interest—the federal laboratory modeled contribution is on the order of a tenth of the Association of University Technology Managers "AUTM" member modeled contribution over the same eight-year time period, 2008-2015.

The overarching federal economic data infrastructure which made this model possible was collected over decades. Fruitful feedback among data users, gatherers, and providers influenced the decision of what data to collect and how to collect it. Models and data improve in concert.

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[52] W. Powell, Kenneth W. Koput, Douglas R. White, and Jason Owen-Smith (2005).American Journal of Sociology, 110 (4), 1132-205. "Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences."

[53] See table 1 of "Guide to FY2018 Research Funding at the Department of Defense (DOD) Contact: James Murday, DC Office of Research Advancement Murday@usc.edu Available: https://research.usc.edu/files/2011/05/Guide-to-FY2018-DOD-Research-Funding.pdf accessed June 3 2018

If there is interest in using these results and this model to continue improving our national technology transfer policies and practices and to make comparisons between federal laboratories and other nonprofit licensors, such as universities, it will be necessary to standardize and harmonize the definitions of at least some of the data elements collected, to collect them over time, and to allocate resources with these goals in mind. Involvement and engagement of stakeholders in the design and implementation of the data gathering system will be key to its success.

Appendix A: Assumptions and Their Effects

Assumption	Effect of Assumption: + means causes an over estimate relative to the estimates in this report – means causes an under estimate relative to the estimate in this report	How handled in Rev 2, or how to handle in future revisions
Relevant sales = (Earned Royalty Income) ÷ royalty rate	+ or - Total impact is a function of ERI, absent direct information on product sales. - Since not all sales generate earned royalty income, "ERI", this assumption leads to an underestimate. Impact overall would increase if this could be adjusted accurately.	Acquire data including, if possible, sales which do not generate royalties because they are to the federal government.
The licensees' production of ERI generating commodities occurs entirely in the U.S.	+ In isolation, this assumption leads to an overestimate.	Rev 2[54]: Assumed/estimated 80% domestic production Acquire data if possible
None of the licensees' sales are final sales.	- Gross output: If a fraction of the licensees' sales are final sales, then it is appropriate to apply an output multiplier to that fraction, thus increasing the gross output estimate. - Employment: If gross output increases, then employment Increases.	Rev 2 modeled the effect of changing this assumption via patterns of final demand for the industries (manufacturing and IT used in Rev 2)
All of the intermediate inputs to gross output are domestic.	+ Gross output: If a fraction of the intermediate inputs to production are not domestically produced, then gross output should be reduced. + Employment: If gross output is reduced, then Employment is reduced	Rev 2 modeled the effect of changing this assumption, both by 1) including intermediate inputs, and 2) by using domestic requirements tables.
All licensees are in a subgroup of manufacturers (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing."	- GDP: Unlike manufacturing, IT generally does not require the expense of a physical plant or factory, and so including IT is expected to increase the GDP estimate, and omitting it, in isolation, leads to an underestimate.	Rev 2 Modeled the effect of changing this assumption, and Included publishing industries, except internet (includes software) (511), Data processing, internet publishing, and other information services (514), Computer systems design and related services (5415). Data on the actual industries, agriculture, for example, with improve estimates, especially when they are disaggregated.
Substitution effects.	+ To the extent a new product actually displaces a current product, unaccounted for substitution effect will result in an overestimate. To the extent it keeps in the U.S. economy activity which would otherwise have been lost, then not a factor	Case by case considerations
Impact ends when earned royalty payments end.	- Likely results in an underestimate of impact.	Studies of product lifetimes, relative to license duration.
No information on license income paid to other institutions or federal laboratories considered.	Worth investigating, particularly Synagis	Look at in more detail

[54] See text of report on factors leading to the selection of .8

Appendix B: FL Data and I-O Multipliers, Rev 1

				Used to calculate: "A portion associated with the License Income received by FL licensors"		Used to calculate "A portion associated with sales by the licensees"	
Source of data	NIST	NIST	BEA	BEA I-O tables	BEA I-O tables	BEA I-O tables	BEA I-O tables
Year	Current dollar FL total License Income	Current dollar FL ERI	Price index for GDP, 2009=100	Output multiplier for total License Income) [55]	Employment to output ratio for NAICS 61[56]	Value added ratio for selected industries[57]	Employment to output ratio for Manufacturers (Licensees) [58]
2008	$171	$133	99.218	0.77	0.0133	0.41	0.0028
2009	$161	$128	100	0.68	0.0128	0.48	0.0029
2010	$155	$119	101.226	0.74	0.0123	0.47	0.0027
2011	$166	$124	103.315	0.76	0.0121	0.45	0.0025
2012	$168	$132	105.214	0.73	0.0119	0.43	0.0024
2013	$185	$145	106.917	0.73	0.0117	0.44	0.0024
2014	$195	$155	108.839	0.75	0.0116	0.44	0.0024
2015	$198	$148	110.012	0.72	0.0114	0.47	0.0024

[55] This is applied to the License Income received by the FL licensors only, and is effectively (1+.73, etc). It was deemed reasonable to look at one level of intermediate inputs since all of nonprofit expenses by definition are consumed by persons, and thus, are final demand. In Rev 1, there is NO output multiplier applied to the licensees' sales. Gross output = 1 x (licensees' sales)

[56] The number of employees required in all industries to meet the FL's level of final demand.

[57] This applies to the licensees' sales only. In this model, 100% of license income received by the FL licensors is contributed to GDP.

[58] For manufacturers in these subgroups: (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing."

Appendix C: FL Data and I-O Multipliers, Rev 2

				Used to calculate "A portion associated with the License Income received by FL licensors"			Used to calculate "A portion associated with sales by the licensees"			
Source of data	NIST	NIST	BEA	BEA I-O tables	BEA I-O tables	Place Holder coefficient	BEA I-O tables	BEA I-O tables	Empirical from the model	Empirical from the model
Year	Current dollar FL total License Income	Current dollar FL ERI	Price index for GDP, 2009=100	Domestic output multiplier for total License Income)[59]	Employment to output ratio for NAICS 61[60]	Modeled domestic production factor[61]	Value added ratio for selected industries[62]	Employment to output ratio for Manufacturers (Licensees)[63]	Licensees' sales related GDP adjustment due to final demand[64]	Licensees' sales related GO adjustment due to final demand[65]
2008	$171	$133	99.218	0.65	0.0130	.80	0.45	0.0030	0.43	0.41
2009	$161	$128	100	0.60	0.0125	.80	0.52	0.0031	0.36	0.35
2010	$155	$119	101.226	0.63	0.0120	.80	0.50	0.0028	0.37	0.37
2011	$166	$124	103.315	0.64	0.0118	.80	0.48	0.0027	0.39	0.38
2012	$168	$132	105.214	0.62	0.0116	.80	0.47	0.0026	0.40	0.38
2013	$185	$145	106.917	0.63	0.0115	.80	0.48	0.0026	0.39	0.38
2014	$195	$155	108.839	0.64	0.0113	.80	0.48	0.0026	0.39	0.37
2015	$198	$148	110.012	0.62	0.0112	.80	0.51	0.0026	0.35	0.35

[59] This is applied to the License Income received by the FL licensors only, and is effectively (1+.65, etc). It was deemed reasonable to look at one level of intermediate inputs since all nonprofit expenses by definition are consumed by persons, and thus, are final demand. Note that in Rev 2, some fractions of intermediate inputs are modeled as OUS. In Rev 2, there IS an output multiplier applied to the licensees' sales. Gross output > 1 x (licensees' sales)
[60] The number of employees required in all industries to meet the FL's level of final demand.
[61] A placeholder coefficient. See discussion in report.
[62] This applies to the licensees' sales only. In this model, 100% of license income received by the FL licensors is contributes to GDP.
[63] For manufacturers in these subgroups: (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing" *and* industry classes 511, 514, 5415, associated with publishing, software and computer systems design and services.
[64] To illustrate how final demand sales increases the licensed product sales contribution to GDP
[65] To illustrate how final demand sales increases the licensed product sales contribution to GO

Appendix D: Rev 1. GDP, Employment, and Gross Output for Federal Laboratories 2008-2015

	FL Contribution to GDP, 1.4% ERI	FL Contribution to GDP, 2% ERI	FL Contribution to GDP, 5 % ERI	FL Contribution to Person Years of Employment Supported, 1.4 % ERI	FL Contribution to Person Years of Employment Supported, 2 % ERI	FL Contribution to Person Years of Employment Supported, 5 % ERI	FL Contribution to Gross Output *no sales to final demand* 1.4 % ERI	FL Contribution to Gross Output *no sales to final demand* 2 % ERI	FL Contribution to Gross Output no sales to final demand 5% ERI
	2009 Dollars	2009 Dollars	2009 Dollars	Person Yrs of Employment	Person Yrs of Employment	Person Yrs of Employment	2009 Dollars	2009 Dollars	2009 Dollars
Year	millions	millions	millions	thousands	thousands	thousands	millions	millions	millions
2008	$4,101	$2,923	$1,272	29	21	10	$9,894	$7,018	$2,990
2009	$4,610	$3,276	$1,407	29	21	10	$9,447	$6,694	$2,840
2010	$4,087	$2,907	$1,255	24	18	8	$8,644	$6,131	$2,612
2011	$3,977	$2,832	$1,229	24	18	8	$8,837	$6,270	$2,677
2012	$4,029	$2,868	$1,243	25	18	8	$9,252	$6,559	$2,789
2013	$4,403	$3,134	$1,358	27	20	9	$9,976	$7,073	$3,009
2014	$4,674	$3,325	$1,437	29	21	10	$10,488	$7,436	$3,162
2015	$4,670	$3,323	$1,437	28	20	9	$9,918	$7,036	$3,000
Total	$34,551	$24,587	$10,638	215	156	73	$76,457	$54,216	$23,080

Appendix E: Rev 2. GDP, Employment, and Gross Output for Federal Laboratories 2008-2015

	FL Contribution to GDP, 1.4% ERI	FL Contribution to GDP, 2% ERI	FL Contribution to GDP, 5 % ERI	FL Contribution to Person Years of Employment Supported , 1.4 % ERI	FL Contribution to Person Years of Employment Supported, 2 % ERI	FL Contribution to Person Years of Employment Supported, 5 % ERI	FL Contribution to Gross Output, *50% share of sales to final demand* 1.4 % ERI	FL Contribution to Gross Output, *50% share of sales to final demand* 2 % ERI	FL Contribution to Gross Output, *50% share of sales to final demand* 5 % ERI
	2009 Dollars	2009 Dollars	2009 Dollars	Person Yrs of Employment	Person Yrs of Employment	Person Yrs of Employment	2009 Dollars	2009 Dollars	2009 Dollars
Year	millions	millions	millions	thousands	thousands	thousands	millions	millions	millions
2008	$5,125	$3,639	$1,559	36	26	12	$11,065	$7,831	$3,303
2009	$5,316	$3,769	$1,605	35	25	11	$10,203	$7,219	$3,042
2010	$4,768	$3,384	$1,445	30	21	10	$9,404	$6,658	$2,813
2011	$4,739	$3,365	$1,442	30	22	10	$9,684	$6,858	$2,901
2012	$4,906	$3,482	$1,488	31	22	10	$10,183	$7,205	$3,037
2013	$5,343	$3,792	$1,621	34	24	11	$10,961	$7,757	$3,272
2014	$5,598	$3,972	$1,696	35	25	11	$11,465	$8,114	$3,421
2015	$5,508	$3,910	$1,672	34	24	11	$10,635	$7,532	$3,188
Total	$41,304	$29,314	$12,528	265	190	86	$83,601	$59,174	$24,977

Appendix F: Comparison of AUTM and FL Contributions to GDP, GO and Employment 2008-2015

	Contribution to GDP, 1.4 % Running Royalties	Contribution to GDP, 2% Running Royalties	Contribution to GDP, 5% Running Royalties	Contribution to Person Years of Employment Supported , 1.4 % Running Royalties	Contribution to Person Years of Employment Supported , 2% Running Royalties	Contribution to Person Years of Employment Supported, 5% Running Royalties	Contribution to Gross Output, Output Multiplier = 1, 1.4 % Running Royalties	Contribution to Gross Output, Output Multiplier = 1, 2% Running Royalties	Contribution to Gross Output, Output Multiplier = 1, 5% Running Royalties
	2009 $	2009 $	2009 $	Person Yrs of Employment	Person Yrs of Employment	Person Yrs of Employment	2009 $	2009 $	2009 $
	millions	millions	millions	thousands	thousands	thousands	millions	millions	millions
Rev 1 AUTM 2008-2015		$316,540	$138,724		2,039	970		$700,257	$301,081
Rev 1 FL 2008-2015	$34,551	$24,587	$10,638	215	156	73	$76,457	$54,216	$23,080

Exhibit A: Approach to calculating a weighted average royalty rate using NIH OTT data

Earned Royalty Income "ERI" from https://www.ott.nih.gov/technology-transfer-metrics and clicking on "Royalty Income by Type"

Product sales data provided in corresponding row via reference to an NIH report

ERI and product sales in thousands of USD

Year	Deflator	ERI current	Product Sales current	ERI constant	Product Sales constant	Royalty Rate	Weighted Average Royalty Rate	Data Source
2009	100	$77,252	$6,000,000	$77,252	$6,000,000	1.2875%		Page 1 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2009.pdf
2010	101.226	$76,663	$6,000,000	$75,735	$5,927,331	1.2777%		Page 3 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2010.pdf
2011	103.315	$83,341	$6,000,000	$80,666	$5,807,482	1.3890%		Page 6 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2011.pdf
2012	105.22	$91,836	$6,500,000	$87,280	$6,177,533	1.4129%		Page 5 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2012.pdf
2013	106.917	$92,221	$7,000,000	$86,255	$6,547,135	1.3174%		Page 5 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2013.pdf
2014	108.839	$115,675	$7,600,000	$106,280	$6,982,791	1.5220%		Page 6 https://www.ott.nih.gov/sites/default/files/documents/pdfs/AR2014.pdf
Total				$513,469	$37,442,271		1.3714%	

Supplementary tables and figures:

Table S-1: Evolution of Application of Input Output Model to Nonprofit License Data

	2009 Report	2012 Report	2013 Research Policy Paper	2015 Report	2017 Report
Years of AUTM Data	1996-2007	1996-2010	1996-2010	1996-2013	1996-2015
Licensees of both HRI's & universities	No	**Yes**	No	Yes	Yes
Jobs supported by licensee's sales are included in jobs estimate.	No	**Yes**	No	Yes	Yes
Updated BEA value added ratios	No	No	No	**Yes**	Yes
Base Year for inflation adjusted dollars	2005	2005	2005	**2009**	2009
The licensees' sales of earned royalty generating commodities occurs entirely in the U.S.	Yes	Yes	Yes	Yes	Yes
None of the licensees' sales are final sales.	Yes	Yes	Yes	Yes	Yes
All of the intermediate inputs to gross output are domestic.	Yes	Yes	Yes	Yes	Yes
All licensees are in a subgroup (chemical products (325), plastics and rubber (326), nonmetallic minerals (327), fabricated metals (332), computer and electronics (334), electrical equipment, appliances and components (335), other transportation equipment (3364OT), miscellaneous manufacturing and machinery (339)) of industry classes 31-33: "Manufacturing."	Yes	Yes	Yes	Yes	Yes
The deflator is for the U.S. economy as a whole, and not industry specific.	U.S. as a whole	U.S. as a whole	U.S. as a whole	U.S. as a whole	U.S. as a whole

Figure S-1

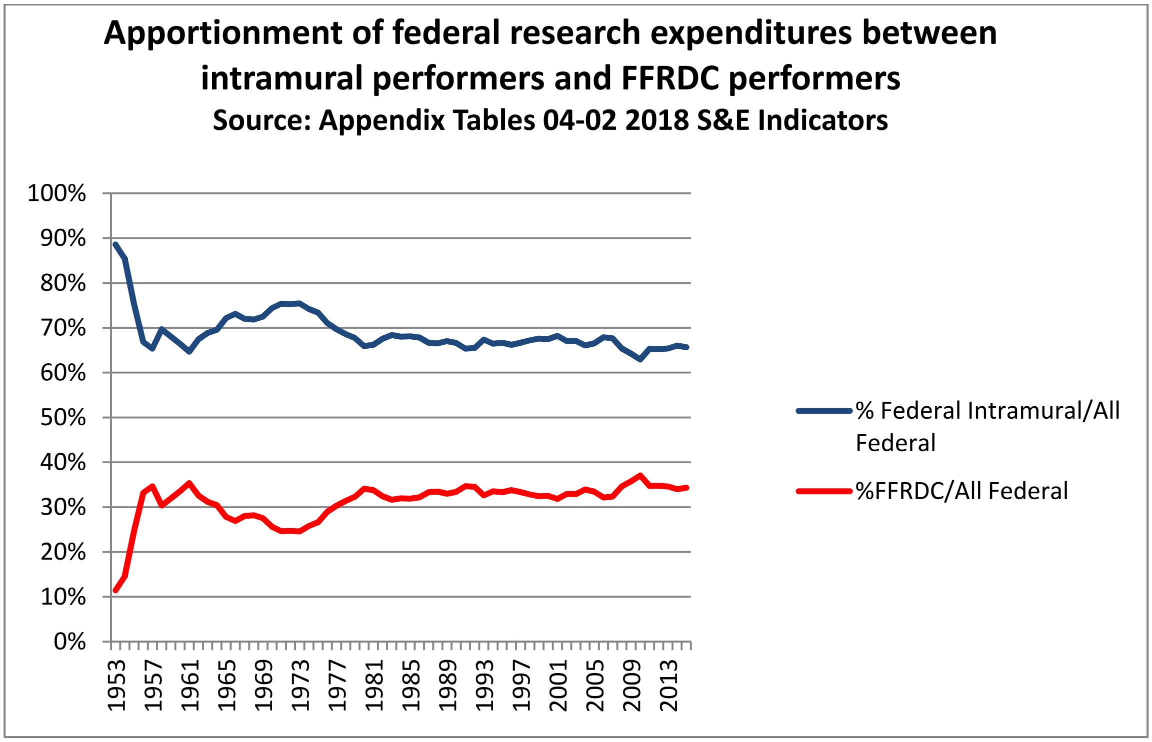

Figure S-2

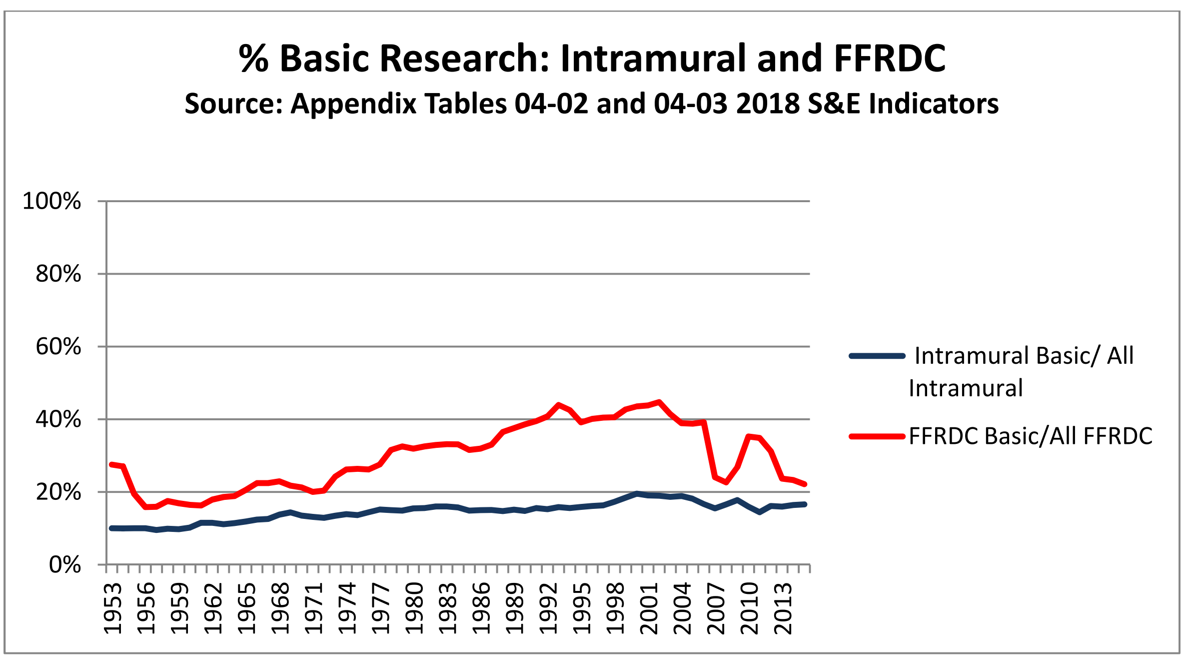

Figure S-3

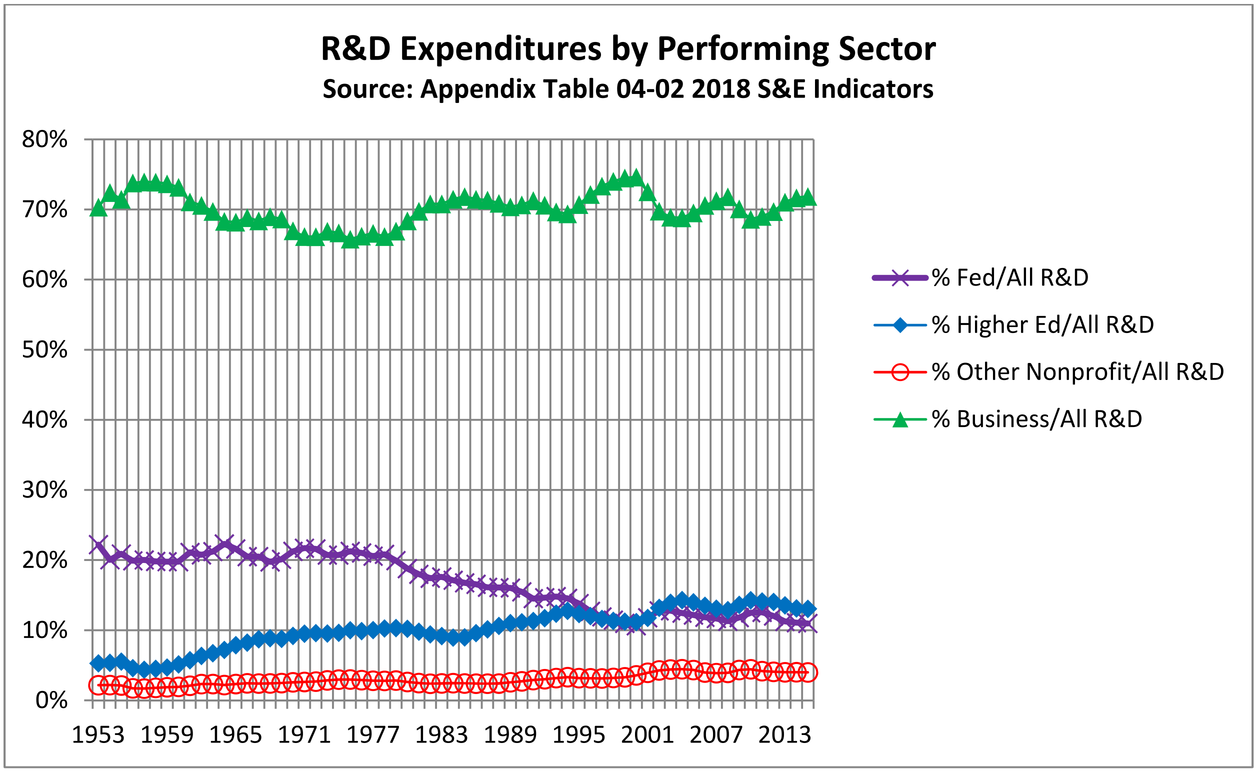

Figure S-4

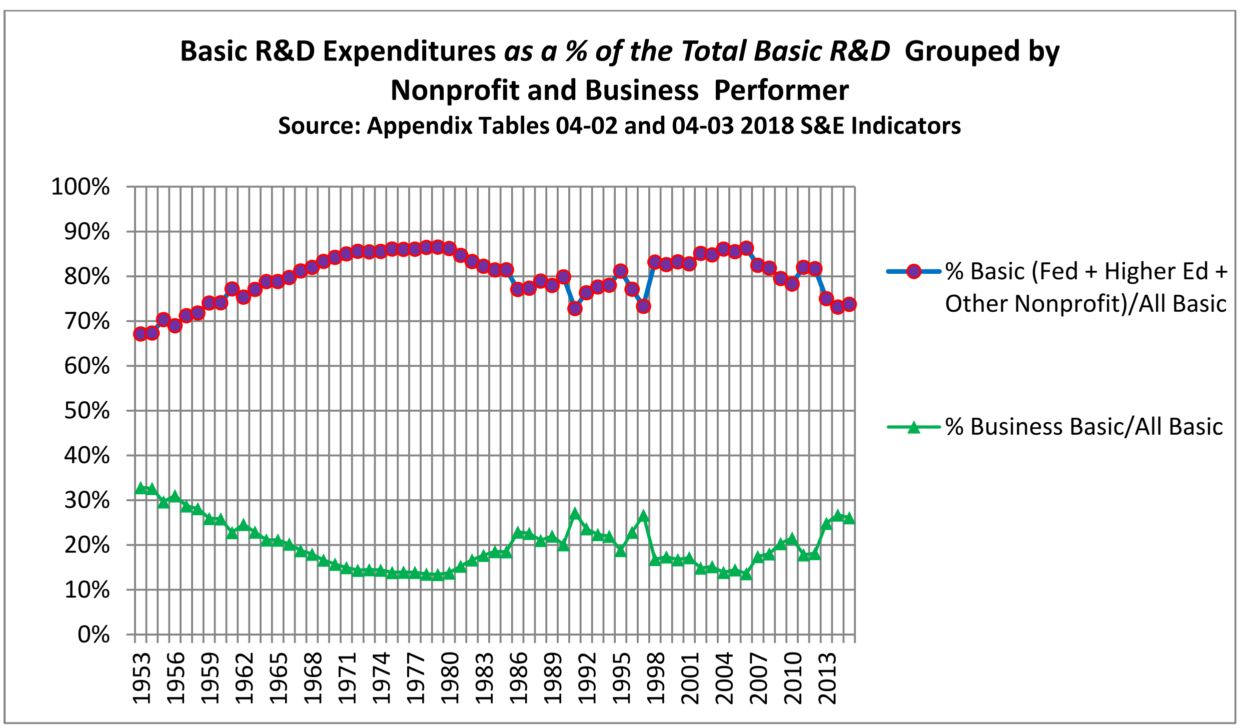

Table S-2

A list of the 20 major industry classes and their two-digit NAICS codes.

11	Agriculture, forestry, fishing and hunting
21	Mining
22	Utilities
23	Construction
31-33	Manufacturing
42	Wholesale trade
44-45	Retail trade
48-49	Transportation and warehousing
51	Information
52	Finance and insurance
53	Real estate and rental and leasing
54	Professional, scientific, and technical services
55	Management of companies and enterprises
56	Administrative and waste management services
61	Educational services
62	Health care and social assistance
71	Arts, entertainment, and recreation
72	Accommodation and food services
81	Other services (except public administration)
92	Government

Table S- 3: Income from Licensing (Dollars in Thousands) Data Received from NIST Nov 2017

Agency	Metric	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
USDA	Total Income, All Active Licenses	$3,953	$5,376	$3,641	$3,989	$3,806	$4,386	$4,928	$5,070
	Invention Licenses	$3,884	$5,318	$3,566	$3,855	$3,671	$4,054	$4,733	$4,845
	Total Earned Royalty Income, (ERI)	$3,010	$4,422	$3,075	$3,137	$3,060	$3,354	$3,611	$3,510
DOC	Total Income, All Active Licenses	$293	$336	$237	$277	$248	$151	$220	$164
	Invention Licenses	$293	$336	$237	$277	$248	$151	$220	$164
	Total Earned Royalty Income, (ERI)	$293	$336	$237	$277	$248	$151	$220	$164
DOD	Total Income, All Active Licenses	$16,057	$16,439	$13,424	$15,682	$7,055	$21,575	$10,890	$8,482
	Invention Licenses	$16,048	$16,165	$13,026	$15,364	$6,552	$20,859	$10,890	$8,482
	Total Earned Royalty Income, (ERI)		$16,240	$10,848	$7,702	$6,335	$20,438	$10,890	$8,482
DOE	Total Income, All Active Licenses	$49,318	$43,570	$40,644	$44,728	$40,849	$39,573	$37,885	$33,137
	Invention Licenses	$43,108	$40,262	$37,065	$40,600	$36,103	$36,068	$32,869	$28,966
	Total Earned Royalty Income, (ERI)	$31,718	$28,901	$25,220	$27,107	$28,735	$27,669	$23,321	$21,245
HHS	Total Income, All Active Licenses	$97,609	$85,059	$80,923	$98,453	$110,576	$116,448	$137,249	$151,727
	Invention Licenses	$94,712	$83,041	$79,805	$82,842	$108,308	$103,664	$133,814	$147,512
	Total Earned Royalty Income, (ERI)	$80,805	$91,060	$91,374	$96,605	$110,930	$116,601	$116,765	$114,102
DHS	Total Income, All Active Licenses	$0	$0	$0	$0	$0	$0	$3	$5
	Invention Licenses	$0	$0	$0	$0	$0	$0	$0	$0
	Total Earned Royalty Income, (ERI)	$0	$0	$0	$0	$0	$0	$3	$5
DOI	Total Income, All Active Licenses	$79	$89	$80	$115	$76	$96	$58	$106
	Invention Licenses	$79	$89	$80	$115	$76	$96	$58	$106
	Total Earned Royalty Income, (ERI)	$79	$89	n/a	$104	$65	$96	$58	$106
DOT	Total Income, All Active Licenses	$18	$44	$17	$18	$7	$9	$23	$12
	Invention Licenses	$18	$44	$17	$15	$7	$12	$0	$0
	Total Earned Royalty Income, (ERI)	$9	$34	$3	$8	$6	$12	$23	$12
VA	Total Income, All Active Licenses	$141	$202	$167	$401	$391	$146	$376	$329
	Invention Licenses	$141	$202	$167	$401	$391	$146	$376	$329
	Total Earned Royalty Income, (ERI)		$205	$133	$401	$392	$390	$376	$329
EPA	Total Income, All Active Licenses	$1,038	$849	$536	$383	$727	$193	$439	$232
	Invention Licenses	$1,038	$849	$536	$383	$727	$193	$439	$232
	Total Earned Royalty Income, (ERI)	$296	$255	$197	$135	$201	$193	$439	$232
NASA	Total Income, All Active Licenses	$2,802	$3,144	$4,517	$3,012	$3,375	$2,183	$2,085	$3,400
	Invention Licenses	$2,725	$2,288	$4,229	$2,877	$3,137	$1,837	$1,920	$3,146
	Total Earned Royalty Income, (ERI)	$1,711	$732	$2,280	$1,525	$1,353	$307	$430	$581
TOTAL	Total Income, All Active Licenses	$171,309	$155,108	$144,186	$167,058	$167,110	$184,760	$194,156	$202,664
	Invention Licenses	$162,046	$148,594	$138,728	$146,729	$159,220	$167,080	$185,319	$193,782
	Total Earned Royalty Income, (ERI)	$117,920	$126,034	$122,519	$137,001	$151,325	$169,211	$156,136	$148,768

Table S- 4 Income from Licensing (Dollars in Thousands) Data Used in Calculation

Agency	Metric	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015
USDA	Total Income, All Active Licenses	$3,953	$5,376	$3,641	$3,989	$3,806	$4,386	$4,928	$5,070
	Invention Licenses	$3,884	$5,318	$3,566	$3,855	$3,671	$4,054	$4,733	$4,845
	Total Earned Royalty Income, (ERI)	$3,010	$4,422	$3,075	$3,137	$3,060	$3,354	$3,611	$3,510
DOC	Total Income, All Active Licenses	$293	$336	$237	$277	$248	$151	$220	$164
	Invention Licenses	$293	$336	$237	$277	$248	$151	$220	$164
	Total Earned Royalty Income, (ERI)	$293	$336	$237	$277	$248	$151	$220	$164
DOD	Total Income, All Active Licenses	$16,057	$16,439	$13,424	$15,682	$7,055	$21,575	$10,890	$8,482
	Invention Licenses	$16,048	$16,165	$13,026	$15,364	$6,552	$20,859	$10,890	$8,482
	Total Earned Royalty Income, (ERI)	$16,057	$16,240	$10,848	$7,702	$6,335	$20,438	$10,890	$8,482
DOE	Total Income, All Active Licenses	$49,318	$43,570	$40,644	$44,728	$40,849	$39,573	$37,885	$33,137
	Invention Licenses	$43,108	$40,262	$37,065	$40,600	$36,103	$36,068	$32,869	$28,966
	Total Earned Royalty Income, (ERI)	$31,718	$28,901	$25,220	$27,107	$28,735	$27,669	$23,321	$21,245
HHS	Income per NIH TT reports	$97,200	$91,200	$91,600	$97,000	$111,200	$116,600	$137,700	$147,000
	Invention Licenses	$94,712	$83,041	$79,805	$82,842	$108,308	$103,664	$133,814	$147,512
	ERI, per NIH TT reports	$79,886	$77,252	$76,663	$83,341	$91,836	$92,221	$115,675	$113,331
DHS	Total Income, All Active Licenses	$0	$0	$0	$0	$0	$0	$3	$5
	Invention Licenses	$0	$0	$0	$0	$0	$0	$0	$0
	Total Earned Royalty Income, (ERI)	$0	$0	$0	$0	$0	$0	$3	$5
DOI	Total Income, All Active Licenses	$79	$89	$80	$115	$76	$96	$58	$106
	Invention Licenses	$79	$89	$80	$115	$76	$96	$58	$106
	Total Earned Royalty Income, (ERI)	$79	$89	$80	$104	$65	$96	$58	$106
DOT	Total Income, All Active Licenses	$18	$44	$17	$18	$7	$9	$23	$12
	Invention Licenses	$18	$44	$17	$15	$7	$12	$0	$0
	Total Earned Royalty Income, (ERI)	$9	$34	$3	$8	$6	$12	$23	$12
VA	Total Income, All Active Licenses	$141	$202	$167	$401	$391	$390	$376	$329
	Invention Licenses	$141	$202	$167	$401	$391	$146	$376	$329
	Total Earned Royalty Income, (ERI)	$141	$205	$133	$401	$392	$390	$376	$329
EPA	Total Income, All Active Licenses	$1,038	$849	$536	$383	$727	$193	$439	$232
	Invention Licenses	$1,038	$849	$536	$383	$727	$193	$439	$232
	Total Earned Royalty Income, (ERI)	$296	$255	$197	$135	$201	$193	$439	$232
NASA	Total Income, All Active Licenses	$2,802	$3,144	$4,517	$3,012	$3,375	$2,183	$2,085	$3,400
	Invention Licenses	$2,725	$2,288	$4,229	$2,877	$3,137	$1,837	$1,920	$3,146
	Total Earned Royalty Income, (ERI)	$1,711	$732	$2,280	$1,525	$1,353	$307	$430	$581
TOTAL	Total Income, All Active Licenses	$170,900	$161,249	$154,863	$165,605	$167,734	$185,156	$194,607	$197.937
	Invention Licenses	$162,046	$148,594	$138,728	$146,729	$159,220	$167,080	$185,319	$193,782
	Total Earned Royalty Income, (ERI)	$133,199	$128,466	$118.736	$123,737	$132,231	$144,831	$155,046	$147,997

Table S-5. Multipliers using License Income, the fraction of License Income which is ERI, 2015 BEA coefficients only, and Rev1 assumptions

	1.4% royalty rate	2% royalty rate	5% royalty rate
$M GDP from both License Income and ERI per $ M of License Income and a known % of License Income which is ERI			
100%	**34**	**24**	**10**
91%	**31**	**22**	**9**
83%	**29**	**20**	**9**
77%	**27**	**19**	**8**
71%	**25**	**18**	**8**
67%	23	17	7
63%	22	16	7
59%	21	15	6
56%	20	14	6
53%	19	13	6
50%	18	13	6
Employment from both License Income and ERI per $ M of License Income and a known % of License Income which is ERI			
100%	**185**	**133**	**60**
91%	**170**	**122**	**56**
83%	**156**	**113**	**52**
77%	**145**	**105**	**49**
71%	**136**	**98**	**46**
67%	127	93	44
63%	120	88	42
59%	114	83	40
56%	108	79	38
53%	103	75	37
50%	98	72	36
GO from both License Income and ERI per $ M of License Income and a known % of License Income which is ERI			
100%	**73**	**52**	**22**
91%	**67**	**47**	**20**
83%	**61**	**43**	**18**
77%	**57**	**40**	**17**
71%	**53**	**37**	**16**
67%	49	35	15
63%	46	33	14
59%	44	31	13
56%	41	29	13
53%	39	28	12
50%	37	27	12

Glossary and definitions:

•Selected definitions from NIST or federal laboratory documents

"Earned Royalty Income" (ERI) is a royalty based on use of a licensed invention (usually, a percentage of sales or of units sold). It is not a license issue fee or a minimum royalty. See page 16
https://www.nist.gov/sites/default/files/documents/2017/09/08/fy2016-doc-tech-trans-report-final-9-5-17.pdf

"Invention licenses" refers to inventions that are patented or could be patented. See page15 Federal Laboratory 15 FY 2015 Technology Transfer Report.
https://www.nist.gov/sites/default/files/documents/2018/04/30/fy2015_fed_tt_report.pdf

No definition found for "Licenses".
See footnote 9 https://www.nist.gov/sites/default/files/documents/2018/04/30/fy2015_fed_tt_report.pdf
"DHS revised their reporting procedure to exclude Trademark licenses for FY 2011 to FY 2015".

This helpful excerpt is from footnote 23 of the "Summary Report on Federal Laboratory Technology Transfer FY 2003 Activity Metrics and Outcomes 2004 Report to the President and the Congress under the Technology Transfer and Commercialization Act". Available here:
https://www.nist.gov/sites/default/files/documents/2016/09/30/summaryreportfy2003.pdf
"Several definitions (used currently by the agencies in reporting) regarding income from licenses are useful to mention here. In general, license income can arise in one or more of several ways: license issue fees, earned royalties, minimum annual royalties, paid-up license fees, and reimbursement for full-cost recovery of goods and services provided by the lab to the licensee (including patent costs).
"Income/royalty-bearing license" = a license whose negotiated terms provide for receipt of income (or royalties) by the licensor.

"**Total income from license**" = income of any form (see above), paid to licensor (in a given year), that arises from an active license.
"**Earned royalty income**" = royalty payment to a licensor that is based on the use of a licensed invention (usually, a percentage of sales or of units sold); not a license issue fee or a minimum royalty. Such payments are earned income from the commercial marketplace, which can be taken as a measure of a lab's active management and successful transfer of its intellectual property.

•Selected definitions from the AUTM 2017 Survey http://www.autmsurvey.org/id_2017.pdf

DATA ACCESS AGREEMENTS: A dataset associated with an invention disclosure, and made commercially available through an "access agreement," may be counted as a license or option. In addition, the revenue derived from that agreement may be counted as license income received. (See Questions 9A1, 9A1, 11B with sub-parts)

LICENSE INCOME PAID TO OTHER INSTITUTIONS: The amount paid to other institutions under inter-institutional agreements. (See Question (11C)). The Survey subtracts it from the TOTAL LICENSE INCOME of your institution to avoid double counting LICENSE INCOME when the receiving institution reports it to the Survey.

LICENSE INCOME RECEIVED: Includes: license issue fees, payments under options, annual minimums, running royalties, termination payments, the amount of equity received when cashed-in, and software and biological material end-user license fees equal to $1,000 or more, but not research funding, patent expense reimbursement, a valuation of equity not cashed-in, software and biological material end-user license fees less than $1,000, or trademark licensing royalties from university insignia. License Income also does not include income received in support of the cost to make and transfer materials under Material Transfer Agreements (See Questions 11B).

LICENSES/OPTIONS:
Count the number of LICENSE or OPTION AGREEMENTS that were executed in the year indicated for all technologies. Each agreement, exclusive or non-exclusive, should be counted separately. Licenses to software or biological material end-users of $1,000 or more may be counted per license, or as 1 license, or 1/each for each major software or biological material product (at manager's discretion) if the total number of end-user licenses would unreasonably skew the institution's data. Licenses for technology protected under U.S. plant patents (US PP) or plant variety protection certificates (U.S. PVPC) may be counted in a similar manner to software or biological material products as described above, at manager's discretion. Material Transfer Agreements are not to be counted as Licenses/Options in this Survey (See Questions 9 and 11).

LICENSE/OPTION AGREEMENTS: A LICENSE AGREEMENT formalizes the transfer of TECHNOLOGY between two parties, where the owner of the TECHNOLOGY (licensor) permits the other party (licensee) to share the rights to use the TECHNOLOGY. An OPTION AGREEMENT grants the potential licensee a time period during which it may evaluate the TECHNOLOGY and negotiate the terms of a LICENSE AGREEMENT. An OPTION AGREEMENT is not constituted by an Option clause in a research agreement that grants rights to future inventions, until an actual invention has occurred that is subject to that Option (See Questions 9 and 11).

RUNNING ROYALTIES:
For the purposes of this Survey, RUNNING ROYALTIES are defined as royalties earned on and tied to the sale of products. Excluded from this number are license issue fees, payments under options, termination payments, and the amount of annual minimums not supported by sales. Also excluded from this amount is CASHED-IN EQUITY, which should be reported separately (See Question 11B1).

•Selected definitions from the Science & Engineering Indicators

These excerpts are provided as a convenience. The 2016 Science & Engineering Indicators can be found here: https://www.nsf.gov/statistics/2016/nsb20161/#/report/chapter-4/glossary

Applied research: The objective of applied research is to gain knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations to discover new scientific knowledge that has specific commercial objectives with respect to products, processes, or services.

Basic research: The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. Although basic research may not have specific applications as its goal, it can be directed in fields of present or potential interest. This is often the case with basic research performed by industry or mission-driven federal agencies.

Development: The systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.