The economic benefits of technology transfer from U.S. federal laboratories

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Abstract:

In this paper we review the legislative emphasis on technology transfers from U.S. federal laboratories, and we present a framework to describe how private sector firms benefit from the adoption of technologies from federal laboratories. We conclude that if a federal laboratory can provide the technology being transferred more efficiently than the private sector can develop it, there is a social gain from the federal laboratory doing so. The social gain will be realized in part by increased profits for the private firms using the technology and in part by consumers who have higher reservation prices for higher quality products and services and who pay lower prices because firms' costs are lower.

Keywords: technology transfer | federal laboratories | R&D

Article:

Introduction and legislative background

Technology transfer is not a new topic within the economics or public policy literatures. While scholars might debate the origin of the phrase *technology transfer*, or even the concept of technology transfer, we doubt that many would argue that an early emphasis in the United States on the transfer of technical knowledge and technology (hereafter simply technology) traces to Vannevar Bush and *Science—the Endless Frontier*.[1]

On November 17, 1944, President Franklin D. Roosevelt sent a letter to Bush in which he articulated a role for, and the national importance of, transferring publicly developed technology to the public and private sectors of the economy[2]:

> Dear Dr. Bush:

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[1] A more detailed discussion of the origin of the concept of technology transfer and the legislative history of U.S. technology transfer related policies is in Link and Oliver (forthcoming).

[2] For a more detailed discussion of Bush's influence on public policy, see Leyden and Link (2015) and Leyden and Menter (2018).

> The Office of Scientific Research and Development, of which you are the Director, represents a unique experiment of team-work and cooperation in coordinating scientific research and in applying existing scientific knowledge to the solution of the technical problems paramount in war. Its work has been conducted in the utmost secrecy and carried on without public recognition of any kind; but its tangible results can be found in the communiques coming in from the battlefronts all over the world. Some day the full story of its achievements can be told.
>
> There is, however, no reason why the lessons to be found in this experiment cannot be profitably employed in times of peace. The information, the techniques, and the research experience developed by the Office of Scientific Research and Development and by the thousands of scientists in the universities and in private industry, should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living.

Bush's June 5, 1945 response to President Harry S. Truman rephrased a portion of President Roosevelt's charge in the form of a question, which Bush himself went on to answer in *Endless Frontier* (Bush 1945, p. 1). That question is: "What can the Government do now and in the future to aid research activities by public and private organizations?" And Bush's answer explicitly emphasized the importance of the role of scientific progress (p. 2):

> The pioneer spirit is still vigorous within this nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress.

Bush's response emphasizes the importance of the transfer of scientific knowledge from the public sector to others to use in the development of new and more productive physical technologies for the betterment of our nation. However, Bush's writings did not address any specific mechanisms for technology transfer, but perhaps it did plant seeds for future public policies that would emphasize the transfer of federally funded and/or developed technologies. Jumping ahead several decades, President Jimmy Carter, as part of his 1979 Domestic Policy Review, specifically emphasized the importance of the transfer of federally funded technical knowledge[3]:

> Often, the information that underlies a technological advance is not known to companies capable of commercially developing that advance. I am therefore taking several actions to ease and encourage the flow of technical knowledge and information. These actions include establishing the Center for the Utilization of Federal Technology at the National Technical Information Service to improve the transfer of knowledge from Federal laboratories; and, through the State and Commerce Departments, increasing the availability of technical information developed in foreign countries.

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[3] See: President Carter's Industrial Innovation Initiatives Message to the Congress on Administration Actions and Proposals (October 31, 1979): http://www.presidency.ucsb.edu/ws/index.php?pid=31628.

In response to President Carter's review, and in response to Congress' awareness and concern about a national productivity slowdown that began in the early-1970s and then accelerated in the late-1970s and early-1980s, Congress passed the Stevenson-Wydler Technology Innovation Act of 1980, Public Law 96-480. The 1980 Act focused specifically on technologies developed in federal laboratories:

> Technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States. … Many new discoveries and advances in science occur in universities and Federal laboratories, while the application of this new knowledge to commercial and useful public purposes depends largely upon actions by business and labor. Cooperation among academia, Federal laboratories, labor, and industry, in such forms as technology transfer, personnel exchange, joint research projects, and others, should be renewed, expanded, and strengthened.

And, the 1980 Act made clear that it is the responsibility of each federal laboratory to establish an office as well as mechanisms to transfer its technology to those organizations that will benefit:

> It is the continuing responsibility of the Federal Government to ensure the full use of the results of the Nation's Federal investment in research and development. To this end the Federal Government shall strive where appropriate to transfer federally owned or originated technology to State and local governments and to the private sector. … Each Federal laboratory shall establish an Office of Research and Technology Applications. Laboratories having existing organizational structures which perform the functions of this section may elect to combine the Office of Research and Technology Applications within the existing organization.

To enhance the technology transfer mission of federal laboratories, Congress amended the Stevenson-Wydler Act of 1980 in 1986 with the passage of the Federal Technology Transfer Act of 1986, Public Law 99-502. The 1986 Act allowed federal agencies to enter into:

> … cooperative research and development agreements [CRADAs] on behalf of such agency with other Federal agencies; units of State or local government; industrial organizations (including corporations, schools and partnerships, and limited partnerships, and industrial development organizations); public and private foundations; nonprofit organizations (including universities); or other persons (including licensees of inventions owned by the Federal agency); and to negotiate licensing agreements … for Government-owned inventions made at the laboratory and other inventions of Federal employees that may be voluntarily assigned to the Government.

In 1990, President George H.W. Bush issued what might be regarded as the first formal statement of U.S. technology policy. In *U.S. Technology Policy* (Executive Office of the President, 1990, pp. 2–6):

> A nation's technology policy is based on broad principles that govern the allocation of technological resources … The goal of U.S. technology policy is to make the best use of technology in achieving the national goals of improved quality of life for Americans,

> contained economic growth, and national security … While the government plays a critical role in establishing an economic environment to encourage innovation, the private sector has the principal role in identifying and utilizing technologies for commercial products and processes … Government policies can help establish a favorable environment for private industry [by taking steps to] … [i]mprove the transfer of Federal laboratories' R&D results to the private sector. Encourage direct laboratory-industry interaction within broad, flexible Federal guidelines, since effective technology transfer occurs at the operational level.

Federal laboratories have traditionally transferred their technology through several mechanisms, although those best known are patenting, licensing, and CRADA activity. Specific emphasis on these three mechanisms of technology transfer, as well as others, gained recent attention in response to the October 2011 Presidential Memorandum—Accelerating Technology Transfer and Commercialization of Federal Research in Support of High-Growth Businesses.[4] President Obama's memorandum about technology transfer was based on the assumption about a positive relationship between technology transfer and innovation, and a positive relationship between innovation and economic growth:

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

Although not a formal technology transfer policy, the Trump Administration has raised important issues about technology transfer from federal laboratories. In The President's Management Agenda (undated), the Administration noted (p. 49):

> The Federal Government invests approximately $150 billion annually in research and development (R&D) conducted at Federal laboratories, universities, and other research organizations. 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.

Under the heading of a Cross Agency Priority Goal to Improve Transfer of Federally Funded Technologies from Lab to Market in the President's Management Agenda (p. 49), the Administration seeks to "Improve the transfer of technology from federally funded research and development to the private sector to promote U.S. economic growth and national security." More specifically, this goal will (p. 49)[5]:

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[4] See, https://obamawhitehouse.archives.gov/the-press-office/2011/10/28/presidential-memorandum-accelerating-technology-transfer-and-commerciali.

[5] As we explain in Sect. 2, formal, systematic quantification of the return on society's investments in federal laboratory/agency R&D has been developed beginning with the seminal work of Griliches (1958). More recent

- Improve the transition of federally funded innovations from the laboratory to the marketplace by reducing the administrative and regulatory burdens for technology transfer and increasing private sector investment in later-stage R&D;
- Develop and implement more effective partnering models and technology transfer mechanisms for Federal agencies; and
- Enhance the effectiveness of technology transfer by improving the methods for evaluating the ROI and economic and national security impacts of federally funded R&D, and using that information to focus efforts on approaches proven to work.

Complementing the U.S. legislative history of emphasizing the social importance of technology transfer from federal laboratories to the private sector, the literature that began with Griliches' (1958) evaluation of the social returns to the federal R&D investment in hybrid corn provides a clear explanation of how one might think about the net economic benefits associated with technology transfer. In the following Sect. 2 we explain the framework and elaborate the ways that private sector firms benefit from the adoption of technology from federal laboratories. In Sect. 3 we offer concluding remarks about the implications to be drawn from our model as well as about the economic benefits of technology transfer from federal laboratories.

A framework for understanding the social consequences of technology transfer

Private sector firms benefit from adopting technology transferred from federal laboratories in two broad ways.

First, the innovative technology may be used directly in production, marketing, or distribution. For example, hybrid corn was used directly in production, lowering the costs of the producers and increasing the consumer surplus in the markets where the corn was sold (Griliches, 1958). For another broad class of examples, as shown in the many studies reviewed by Link and Scott (2013), industry's use of the infrastructure technology created with the federal R&D in the laboratories of the National Institute of Standards and Technology (NIST) facilitates not only the production of goods and services, but also their marketing and distribution, lowering costs by facilitating transactions between the producers and their customers.

The second of the broad ways that private sector firms use the technologies created by the R&D in federal laboratories is as input into the private sector's own R&D. In this case, the private firms' R&D costs are lowered; and thus, the rate of return on their R&D investments increases. Further, when the products developed are sold in markets that are not perfectly competitive, the firms will be able to sell their higher quality products and services at mark-ups over post-innovation production costs. Downstream customers benefit too. Firms that purchase the innovative products and services developed from technology resulting from federal R&D have

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approaches to quantifying a return on the federal R&D include Link and van Hasselt (2019, p. 66) who suggest, based on their independent analysis of federal agency technology transfer patent data, the following: "Our measure of the patent application elasticity with respect to agency per capita R&D of around 1.06 might be interpreted as a dimension of the social returns to public sector investments in R&D generated through newly patented knowledge. While not a traditional ROI measure as called for in the President's Management Agenda, our findings do motivate the need for further study of the social impact of publicly funded R&D outputs from federal agencies."

lower costs and, to the extent that the lower costs are not completely passed through in lower prices for their products, higher profits. And, consumers ultimately realize greater consumer surplus using products and services with higher quality and/or lower prices.

Figure 1 illustrates the broad case where the technology from federal R&D is used directly in production, marketing, or distribution and thereby creates economic surplus. The benefit of R&D investment in Griliches' (1958) evaluation is the stream of surplus created by the innovation resulting from the federal R&D.[6] In the case illustrated in the figure, the surplus is entirely consumer surplus because the market in which the new technology is used is perfectly competitive. That is the case that Griliches (1958) used for the transfer of hybrid corn technology from federal research stations to the private sector.

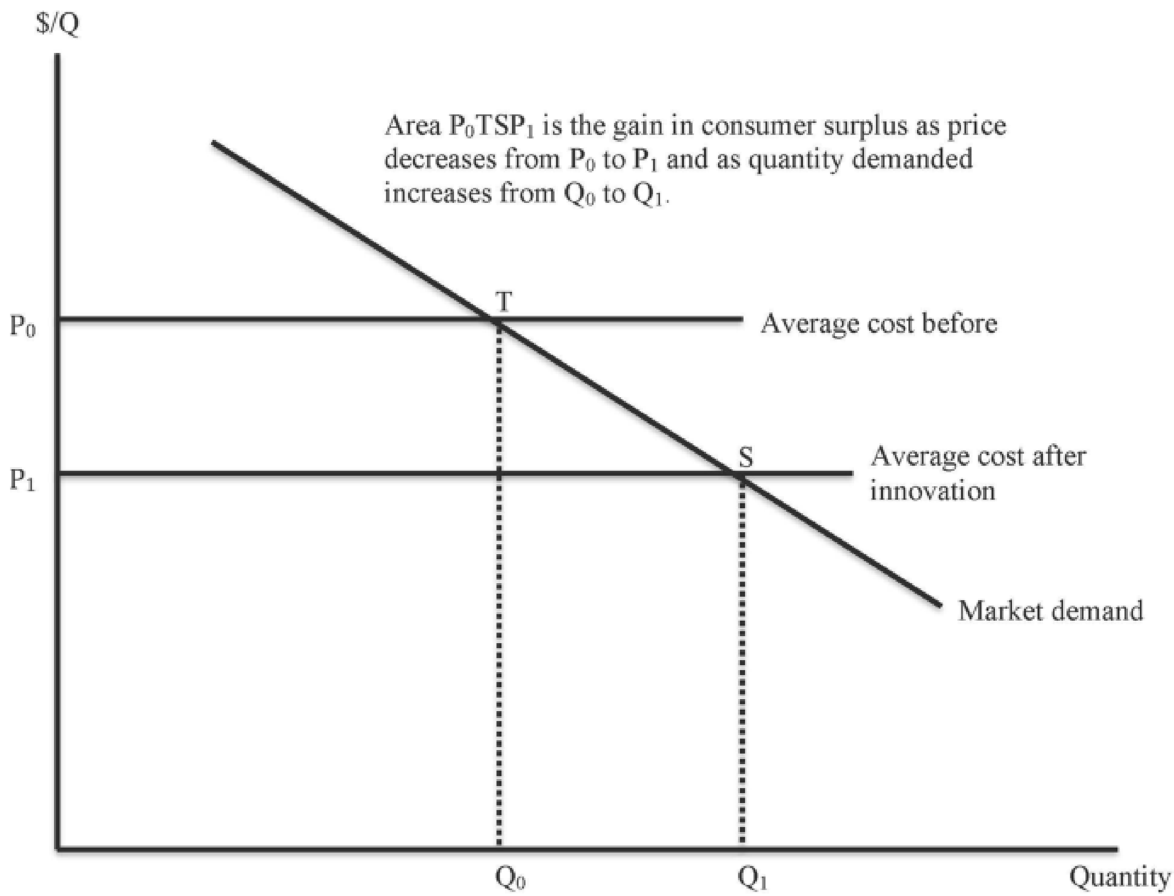

Fig. 1. Gain in economic surplus from process innovation in a competitive market in the case of long-run constant unit costs *Source*: Based on Link and Scott (2013)

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[6] As Link and Scott (2013) explain, this approach assumes that the counterfactual scenario in the absence of the federal R&D would have been the status quo ante. If instead, private industry would have performed the R&D in the absence of the federal R&D, the benefits of the federal R&D would be the R&D costs avoided by the private sector and any surplus shortfall, from the economic surplus with the federal R&D, that would have resulted if the private sector had performed the R&D. If the private sector simply would not have performed the R&D that the federal laboratory provides, no R&D costs would have been avoided by the private sector and the shortfall in surplus would be complete, and the benefit stream from the federal R&D technology transfer is just as Griliches described.

Mansfield et al. (1977) extended the Griliches model to consider cases where products are sold in markets that are not perfectly competitive, and also to consider cases where the new technology not only lowers the cost of producing a product already produced (such as hybrid corn reducing the cost for producing corn), but also where a new product is being sold. As another example, Fig. 2 illustrates a case detailed in Link and Scott (2005) where the use of new technology—a new standard reference material that was developed with federal R&D at NIST—enabled a new calibrating instrument that cost less to develop and produce and could be sold at a price greater than average production cost. The new standard reference material, SRM 2517a, provided wavelength references needed to calibrate the instruments—such as optical spectrum analyzers, tunable lasers, and wavelength meters—used to characterize the components of wavelength division multiplexed (WDM) optical fiber communications systems.

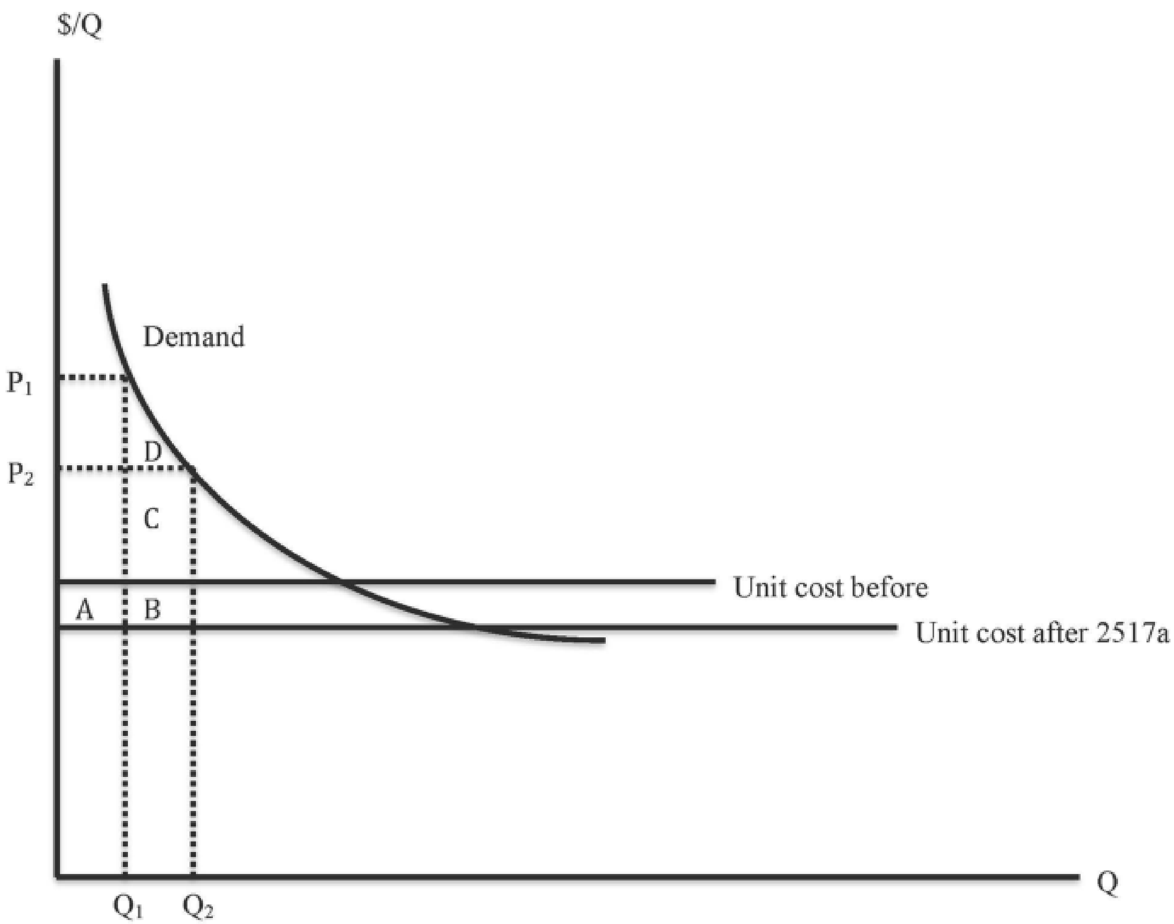

Fig. 2. Demand, unit cost, and net gain in producer and consumer surplus from the use of SRM 2517a *Source*: Based on Link and Scott (2005)

Figure 2 represents the situation for a firm selling a differentiated product that used the new SRM 2517a. The figure illustrates that the availability of the new standard reference material lowers the firm's unit costs from "unit cost before" to "unit cost after 2517a." Consequently, the firm chooses a lower price and sells more of its product or service. The firm's profit maximizing price falls from P_1 to P_2, and the optimal level of output increases from Q_1 to Q_2. The new surplus—resulting because of the new lower unit costs of production enabled by SRM 2517a—is the sum of the areas A, B, C, and D in the figure.[7]

The technology providing wavelength references for the calibration of optical instruments is one that illustrates both of the broad ways that private firms can benefit from the transfer of technology generated by federal R&D. The wavelength references were used in both R&D investments in new products and in the production and distribution of goods and services. When we focus on the second broad category of benefits—the benefits to private firms from using in their own R&D projects the technology developed with the federal R&D—a third figure is useful.

Figure 3 complements Figs. 1 and 2, and together the three diagrams represent a framework to explain what might be called the economics of technology transfer, and in our case the transfer is from federal laboratories.[8] Figure 3 provides a direct look at the analytics of the firm's R&D investment decision for the project that will use the technical knowledge or technology created by federal R&D investments. We rely on Fig. 3 to make a distinction about the efficiency of the transfer of technology from federal R&D as contrasted with the efficiency of direct government subsidies of private R&D investment more generally.

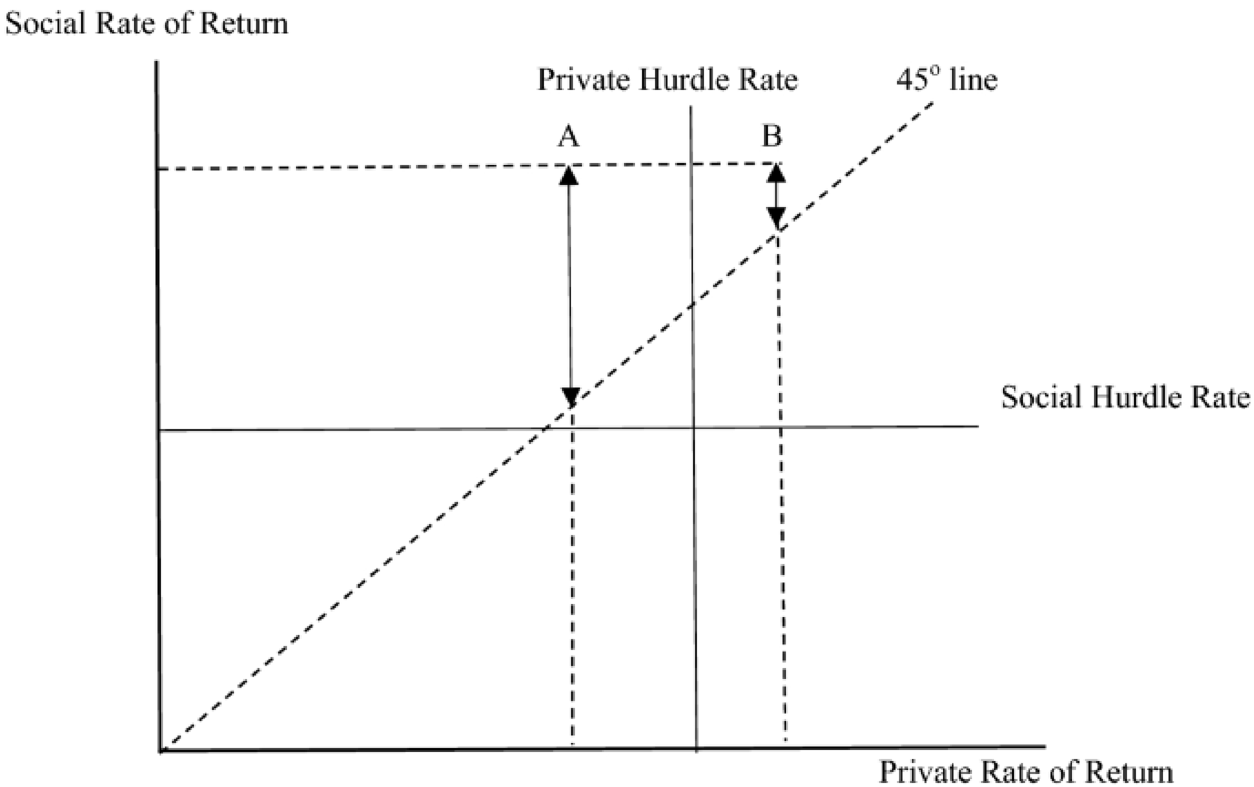

Fig. 3. Identifying R&D projects that benefit from a technology transfer based policy incentive
Source: Based on Link and Scott (2010)

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[7] Area A represents the new producer surplus on sales of the original amount of output. Area B plus area C represents the new producer surplus from the sale of additional output. Finally, area D represents the net gain in consumer surplus (new consumer surplus that does not simply offset a loss in previously existing producer surplus).
[8] See Schacht (2012) for a thorough heuristic argument about the benefits of technology transfer

In Fig. 3, observe that the horizontal axis measures a firm's private rate of return from its own self-financed R&D project, and the vertical axis measures society's associated social rate of return from this same project. Also note that the firm's hurdle rate (i.e., the minimum acceptable expected rate of return from an R&D project) and society's hurdle rate (i.e., the minimum acceptable expected rate of return from an R&D project conducted by a firm) are referenced on the horizontal and vertical axes.[9] A 45-degree line is imposed on the figure to allow for a private or a social rate of return to be mapped from one axis to another.

For a firm, consider two R&D projects, A and B. We emphasize that projects A and B are R&D investment projects in the context of our focus on how technology transferable from a federal laboratory enhances a firm's R&D activities. The social rate of return associated with both projects is greater than society's hurdle rate, so society would like to see this firm pursue both projects.[10] However, the expected private rate of return for project A is less than the firm's hurdle rate or required expected rate of return, so the firm will not pursue project A on its own, assuming that it must use only its own resources. In the case of project A, a policy to provide an incentive for the firm to accept the investment project would need to move the expected private rate of return to, or to the right of, the firm's hurdle rate. If the policy incentive is the provision of a direct subsidy with the government essentially paying part of the investment cost with a grant or a tax break, then if the policy is efficiently designed (in the sense that the taxpayers pay no more than necessary toward the firm's R&D investment project), it will move project A's private expected rate of return exactly to, or perhaps an amount epsilon beyond, the firm's private hurdle rate. For such public policies, projects such as project B with expected private rate of return already greater than the firm's private hurdle rate do not require the subsidy, because the firm will pursue project B on its own using its own resources.[11]

However, if the situations shown for projects A and B are depicting the investment projects without the availability of the federal R&D generated technology—for example, an R&D project to develop, in the absence of SRM 2517a, an aspect of a WDM optical fiber communications system—then whether the project A's expected private rate of return is shifted to the right of the hurdle rate because of the availability of a new technology from federal R&D, or instead the project B's expected private rate of return is increased, the transfer of the new technology is efficient. For case A, it enables a required expected rate of return and thereby enables a socially valuable project. For project B, the R&D costs are again lowered, just as was the case for project A, but unlike the situation with the direct subsidy, the transfer of the technology is efficient for project B as well as for project A. With project B, the firm's private expected rate of return, even without the transfer of the federal technology, is higher than it needs to be to get the firm to

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[9] Our discussion about Fig. 3 assumes that we have probability distributions—they could be completely diffuse and subjective, or they could be based on experienced frequencies, but we have them, and then we have the expected values being used. The mathematical expectation is a summary measure of an infinite number of things that could happen given a continuous distribution, and we do not discuss how the expectations about rates of return from R&D projects are formed. Link and Scott (2010) provide further discussion of the figure, its origins, and its underlying assumptions.

[10] We assume that a social rate of return is known. Link and Scott (2011) provide detailed discussion of the social rate of return that has been used in the context of evaluating the social value of federal R&D investment projects.

[11] In our comparison of the firm's behavior regarding projects A and B, we are assuming that the firm is motivated by its own self-interest and not by what might be in the best interest of society.

accept the project. With the technology transfer, the firm's private rate of return is still higher, but that is not because the taxpayers were paying it more in subsidy than it needed. It is, instead, because the use of the technology developed by the federal R&D investment is being put to use in the private sector and generating profits for the firm (raising its private expected rate of return), and typically also generating producer surplus for other firms and consumer surplus for customers. It is precisely those surplus gains that are being measured as the benefits for the transfer of the technology SRM 2517a in Fig. 2 when the technology is used in a private firm's R&D investment to develop a new product or a new process technology.

Discussion

Technology transferred—from a federal laboratory to a private sector firm though any of a number of transfer mechanisms—represents a transfer of either R&D-based knowledge or a R&D-based technology that could enhance the firm's private rate of return on project A or project B. When the technology transfer has that effect, policy incentives to promote such a technology transfer would be in the best interest of society.[12] For project A, the transfer of the federal R&D developed technology gets the firm over its hurdle rate and it then is able to invest in the socially valuable project; for project B, the firm's expected rate of return will be even higher than what would have been sufficient to provide incentive to invest, but those rents are a part of the benefits that justified the public's investment in the federal R&D investment. In this context where we are not talking about subsidizing the private R&D project with a direct grant or a tax break, there is not the issue of making the subsidy just large enough to get the firm over the hurdle rate and no more. Instead, if the federal laboratory can provide the technology being transferred more efficiently than the private sector, there is a social gain from doing it that way. The social gain will be realized in part by increased profits for the private firms using the technology (whether for production or R&D, and whether for a R&D project like project A or like project B) and in part by consumers who have higher reservation prices for higher quality products and services and pay lower prices because firms' costs are lower.

Additional research is needed not only on the history and application of public sector initiatives related to the transfer of technology from publicly funded laboratories and/or institutions in other countries, but also on evaluations of the social benefits attributable to the transferred technologies. Case studies are an appropriate approach for such research. Case studies are a means to validate the framework suggested in this paper, and they are a vehicle for emphasizing the context associated with the motivation for and practice of technology transfer.[13]

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[12] As explained in Sect. 2, for the policy incentives of a focused tax policy or a direct R&D award, the incentives would be used just for project A to avoid spending taxpayers' money when no incentives are needed for the firm to make the R&D investment.

[13] See Link and Scott (2013) for the theory and many examples of the evaluation of the benefits from the transfer of technology developed in U.S. federal laboratories. A subset of the benefits results from the use of the transferred technology in private-sector investment projects. While not a technology transfer study, also see Link and Scott (2001) for a method that offers a framework for evaluation of the social benefits associated with a privately developed technology (or an investment project more generally) that benefits from the reduction in development costs, or from an increase in its quality, from the use of the transferred technology. Thus, the framework could be adapted to evaluate the social benefits of transferring government-developed technology to private firms for their use in their own investment projects.

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