The Public Policy Background and the Economic Case for Intellectual Property

To answer the question of why ARS patents and what it does with the patents it holds, we focused particularly on case studies of technologies patented and licensed by the agency. The case study methodology provides detailed information from interviews with the actors in the process—the inventors, the patent and technology transfer specialists, and the licensees. Case studies can lead researchers to conclusions that are obvious to practitioners but not evident from data (Helper, 2000). Case study information does not allow statistical tests, however, so it needs to be complemented by other empirical information to support the conclusions drawn. In this report, "other empirical information" includes:

(1) A history of U.S. patent institutions and their hypothesized functions

(2) Brief discussions of data on Federal Government activity in scientific research and technology transfer

(2) Equivalent data for ARS as the agency principally responsible for agricultural research within the Federal Government

(4) The alternative technology transfer mechanisms used by ARS

The aggregate data demonstrate the change in the Federal Government's patenting and licensing strategy since the 1980s. For many years, the Federal Government often took title to the patentable research it funded. Licenses, if any, were nonexclusive, and many Federal patents were considered to have little commercial value. Following the policy changes of the 1980s, patenting and licensing increasingly became instruments of Federal technology transfer policy. This study of ARS looks in detail at the operation of an office of technology transfer (OTT) in a particular Federal agency, and clarifies the ways in which such an OTT accomplishes technology transfer through patenting and licensing.

Constitutional Law and Incentives for Science

Intellectual property law in the U.S. arises from the U.S. Constitution. Article I, section 8, of the U.S. Constitution states:

> *Congress shall have power ... [t]o promote the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries.*

Over time, Congress used this power to pass laws for the encouragement of inventive and creative efforts. The Patent Act of 1790 was the first such law. Patent law provides the economic incentive to undertake such efforts because of the temporary exclusive rights of owners to generate income from these inventions. Thomas Jefferson, first head of the Patent Office, believed that inventive activity was the engine of growth. At the same time, the idea of owning new knowledge and inventions conflicted with the idea that new knowledge should be freely available to encourage further inventiveness and economic growth. For Jefferson, the role of the patent office was to encourage and disseminate inventions, not conceal or contain them. Because of these beliefs he formulated a policy for patents that encouraged invention but maintained restrictions on what could be patented. That policy is essentially the basis for our patent law today.

An Overview of Intellectual Property

Intellectual property rights (IPR), such as patents, copyrights, and trade secrets, protect new creations from imitation and competition. The major policy objective of IPR is to restrict temporarily the number of suppliers in a market in order to provide incentives for innovation by allowing innovators to reap commercial success from their creations. In return, society gets new products and services, as well as voluntary disclosure of the technology needed to create them. Intellectual property rights usually last for a limited period; when intellectual property rights expire and an invention is no longer protected, anyone is free to compete against the original inventor. In general, granting IPR aims to sacrifice short-term market efficiency for long-term economic gains (King, 2001).

An important role of IPR is to create a market for innovation. Institutions or individuals with important intellectual property assets do not necessarily possess the complementary assets, commercial skills, or market presence necessary to bring their products to market. IPR provide inventors a negotiating tool with which to license or sell an invention to other firms better positioned to commercialize it.

However, IPR also have drawbacks. They insulate IPR owners from competition, creating market inefficiencies. Protected markets permit higher prices that may maximize profits but may also restrict the widespread use of new inventions. IPR owners might also feel less incentive to innovate because they risk cannibalizing their own markets (Reinganum, 1983). Strong IPR also might hinder innovation if granted for a research tool or fundamental technology necessary for future improvements. While IPR can be licensed to other parties, owners of these kinds of IPR might refuse to grant licenses for strategic reasons. The problem could compound in areas of rapid and complex research in which many licenses might be necessary for further improvements, because the owner of any one of them could hold up further research (Heller and Eisenberg, 1998; Shapiro, 2001).

The net social gains from intellectual property (IP), particularly the patent system, sometimes are assumed to be positive. That is, the benefits to society from greater innovation are thought to outweigh the costs of market power or research holdup. This has certainly been the reasoning behind the major changes in IP policy in recent years. However, the empirical evidence to support this contention is limited and nuanced. Patents are only one of a number of factors that motivate invention, and their influence may be stronger in some industries, such as pharmaceuticals and chemicals, than in others. This might be caused in part by the combination of relatively high research intensity in these industries with the fact that new drugs or chemicals typically are composed of a relatively small number of patentable components (Scherer et al., 1959; Taylor and Silberston, 1973; Mansfield

1986; Levin et al., 1987; Cohen et al., 2000). Differences in the operation of IP systems do result in subtle economic differences. For example, the Japanese system is designed in part to promote greater intra-industry knowledge spillovers than the U.S. system is (Cohen et al., 2002). It has become particularly difficult to measure the economic impacts of the U.S. patent system in recent years because of the large policy changes in that system that started in the 1980s and are still ongoing (Jaffe 2000).

Empirical studies of the economic impact of patent protection fall into one or more of several subcategories:

(1) the impact of patents on innovation

(2) the impact of patents on the disclosure of inventions

(3) the impact of patents on technology transfer (Gallini, 2002)

Empirical research also has been initiated in response to criticisms of stronger patent protection, in particular problems associated with new subject matter, changes in the standard for nonobviousness,[3] and the rise in patent litigation costs (Gallini, 2002; see also Mazzoleni and Nelson, 1998).

[3]U.S. utility patents—the main patent category, as contrasted with other types such as plant patents—must meet standards of usefulness, novelty, and nonobviousness. "Nonobviousness" means the patented technology must not be obvious to an individual "skilled in the art."

The greatest empirical interest has concerned the question of the impact of patents on innovation, but strong patent protection also may promote vertical specialization and reduce transactions costs in negotiating contracts during the process of technology transfer (see a review in Gallini, 2002, especially pp. 141-144). Reduction of transactions costs has been considered particularly important in technology transfer from universities to industry (Jensen and Thursby, 2001; Hellmann, 2005).

Our study is particularly concerned with the impact of patents on the development and commercialization of inventions already produced by public sector institutions, in particular by the Agricultural Research Service (ARS) of the U.S. Department of Agriculture. Our focus is on the economic interaction between the IPR and technology transfer, and on how this interaction affects public research outcomes.[4]

[4]Technology-transfer specialists may define "technology transfer" as "conversion of intellectual assets into goods and services functional for end users." Some social-science research emphasizes the types of actors involved in domestic technology transfer, for example the transfer of technology from the public to the private sector, between private-sector institutions, or between public-sector institutions. In other studies, the term "technology transfer" refers to the transfer of technology among countries, in particular from industrialized to less-developed nations. Different definitions of technology transfer can overlap. In this study we focus both on the conversion of intellectual assets and on the roles of the public and private sectors.

Approaches to the Empirical Study of Technology Transfer

One analytical approach to technology transfer is from the "market failure" perspective. In this approach, competitive markets allow buyers and sellers to communicate through price signals, leading to an efficient level of production. At times, however, markets fail to produce an efficient amount of a good for several reasons.

One of these reasons is the existence of "externalities." Externalities occur when production or consumption of a good affects a party external to the transaction. A "positive externality" occurs when a transaction benefits a party external to the transaction. For instance, a homeowner who purchases flowerbeds and landscaping services to beautify the exterior of her house also benefits the next-door neighbors, who might enjoy the beauty of the flowers and an increase in neighborhood property values. The neighbors receive a benefit from the purchases, although they are not directly involved in the transactions that create the benefit. The same example generates a "negative externality" if the transaction imposes costs on the neighbors: pollen from the flowers might cause an allergic reaction, necessitating medical expenses.

Lack of competition is another potential source of market failure. A limited number of sellers or buyers in a market may distort prices and keep the volume of transactions below the efficient level, resulting in prices that are too high and quantities exchanged that are too low compared with prices and quantities in a competitive market. Antitrust law exists to prevent this market failure. For example, the United States District Court of the District of Columbia held in 1998 that Microsoft Corporation "could charge a price for [the Windows operating system] substantially above that which could be charged in a competitive market."[5] Additional competitors lower prices and increase the total social benefit of the market (albeit at the expense of the monopolist).

[5](C.A.98-1232)

Markets might also fail to produce an efficient amount of a good when it is "nonexcludable" or "nonrival" (or both). Nonexcludability and nonrivalry are the two basic concepts used to define public goods. A nonexcludable good can be consumed by anyone for free. In the earlier gardening example, the homeowner cannot easily prevent people from enjoying the beauty of the flowers. (The homeowner could erect a fence and charge admission to the garden, so this particular good might be partially excludable.) Suppliers of nonexcludable goods can have difficulty forcing consumers to pay, and therefore nonexcludable goods are sometimes undersupplied. A nonrival good is one that many people can consume without diminishing the consumption of others, such as radio broadcasts and fireworks displays. Precisely because nonrival goods can be enjoyed so broadly, markets can undersupply them, which is socially inefficient.

The existence of market failures is often a basis for public intervention. Intervention might take the form of a tax policy to discourage negative externalities, a subsidy policy to encourage positive externalities, or antitrust policy to increase competition.

Public investments in research and development (R&D) are another response to market failure. Public R&D generates new information, in the form of scientific knowledge. Information is sometimes considered a pure public good. It is nonrivalrous, in that information can be understood and used by everyone simultaneously. It is also difficult to exclude, because many ways exist to convey information inexpensively. Because it displays both of these characteristics, information created by publicly provided R&D is often considered a public good.

Public research also can address problems of market failure more directly. Federal laboratories can research new technologies to reduce pollution byproducts of manufacturing. The research is itself a public good, in the sense that it generates information that is nonexcludable and nonrival. In addition, the subject of the research is aimed at correcting a market failure arising from the negative externalities of pollution.

Although universities, the Federal Government, and private firms all may conduct research with some public-good aspects, universities often are regarded as the primary source of public-good research. For much of their history, U.S. universities emphasized engineering and applied technology development more than they did basic research (Rosenberg and Nelson, 1994). Following World War II, U.S. universities became one of the world's most important sources of public-good research, a role consistent with the market-failure paradigm (Bozeman, 2000).[6] These two roles—provision of information with public good externalities, and research in areas where market failure is an issue—represent the public response to market failure in this approach to technology transfer.

[6]In many instances, students of research policy distinguish between basic and applied research. However "basic research" is not always identical with "public goods research," nor is "applied research" always identical with "private goods research." "Some applied research serves to develop public goods, and some basic research results can be held as private goods depending on how they are disseminated" (Just and Huffman, 2004). This is part of the context for our remarks on the development of pollution control technology, for example.

There are analytical approaches other than "market failure" to the study of technology transfer. The "mission technology" paradigm "assumes that the government should perform R&D in service of well-specified missions in which there is a national interest not easily served by private R&D" (Bozeman 2000). The pre-eminent example of mission-related technology development in the U.S. is defense- and national security-related R&D. Civil engineering or sponsorship of the National Armory—which helped in the development of manufacturing techniques using interchangeable parts and mass production—are among the earliest examples of research in support of the military mission. Agricultural research and extension was another relatively early example of mission-related research, with some activities such as seed importation and classification carried out by the Agriculture Division of the Patent Office even before the establishment of the U.S. Department of Agriculture in 1862 (Dupree, 1986; Hounshell, 1984; Huffman and Evenson, 1993).[7]

[7]Other currently important government mission research areas are medicine and public health, energy production and conservation, and space (Bozeman, 2000).

Finally, the "cooperative technology policy" paradigm stresses cooperation among industry, government, and universities, and cooperation among rival firms in the development of precompetitive technologies (Larsen and Wigand, 1987; Wigand and Frankwick, 1989; Link and Tassey, 1987). In this paradigm, government can serve both as a research performer and as a research broker, developing policies that affect industrial innovation. This paradigm is based on the belief that government technology planning and coordination can enhance innovation and productivity. The cooperative technology policy paradigm is one of the major factors behind the many policy changes, including changes in IP policy, which began in the 1980s. However, this paradigm is sometimes in conflict with the market failure paradigm that characterizes many economists' thinking on IP and technology transfer policy (Bozeman, 2000).[8]

[8]In the "market failure" paradigm, the government's role is seen as residual; in the "cooperative technology policy" paradigm, the government plays a considerably more active role in coordinating research across sectors.

The Economic Case for Intellectual Property in Federal Technology Transfer

The objective of a Federal office of technology transfer (OTT) is to serve the public interest by maximizing the value of Federal research.[9] In many cases, the public interest is best served by the publication and wide dissemination of Federal research, placing it in the public domain where anyone can put it to use. However, when Federal research creates a product or technology with potential commercial applications, laws provide scope for further development by private sector firms. In this way, the government can

[9]The Stevenson-Wydler Act mandated "that all major Federal laboratories establish an Office of Research and Technology Applications to undertake technology transfer activities" (Jaffe and Lerner, 2001).

pursue Federal research priorities and provide incentives for the development of resulting technologies, and at the same time harness the economic efficiency of market competition.

Generally speaking, technology developed with the support of Federal research is not immediately ready for commercialization. A technology developed to the point of patentability might require further investments in research and development before it can be marketable. A scientist may patent a plant trait with beneficial agronomic properties, but it is unlikely that the invention can succeed commercially unless it can be incorporated into a crop variety with a competitive yield. Likewise, a patented mechanical process or invention might work well at a small scale, but it might need additional development to realize its benefits at a larger scale. Additional research might be necessary to improve a technology and learn more about its properties, or additional development effort might be necessary to integrate the technology into a feasible production process. Commercialization is the final step, incurring marketing and advertising costs along with production costs.

When additional investments in research and development are necessary to commercialize a patented technology, firms may be willing to pay money up front to develop a technology that is expected to be profitable in the future. The licensing fee they pay to a Federal OTT is usually only a small fraction of all the investments they make before a technology breaks even: R&D expenses, capital costs, marketing, and advertising are among them. Companies that invest are risking their capital and effort, and they must expect a suitable return on their investment to be willing to license a technology. Patents play an important part in increasing the perceived profitability of a technology, since patents limit competition in the early stages of business development.

Technology licensees face two distinct types of risk—"technology risk" and "appropriation risk." Technology risk is the chance that a technology can be improved and developed into a feasible commercial product or process. The technology must not merely work; it must be an improvement over available alternatives for the additional expense of development to be worth the investment.

Appropriation risk is the likelihood that a company is able to reap profits successfully from its investments in the new technology. After a released technology is found to be profitable, competitive forces put pressure on profits. Competitors might lower prices, or existing companies and new entrants might try to imitate the new technology. In time, competitors can try to "invent around" the technology to achieve the same result in a different way. Other inventors might create further improvements to the technology and capture market share and profits that way. In the long run, new inventions, technologies, and changing production practices and customer choices limit the possible profits even when a technology is patented. If a commercial partner is not found, because the Federal Government is not likely to bring the invention into commercial production, it is improbable that the technology will have widespread impact.

The Stevenson-Wydler Act reduces appropriation risk for potential licensees by providing scope for patent protection of federally funded research. This reduction in risk encourages the additional investments necessary for technology commercialization, and increases the likelihood that Federal research can be transformed into commercial applications. Without patent protection, appropriation risk is typically very high, especially if competitors are able to learn from the additional investments made by the first developer. Patent protection may help to solve the potential problem of "me too" developers. If no one wants to develop the technology first because most of the profits from the invention are earned by subsequent developers, even the first steps toward eventual commercialization of the technology may be stymied.

The government has other means to transfer technology; one is by publishing research.[10] When an OTT believes that the best way to maximize the value of Federal research is to issue licenses, it must balance the incentives offered to licensees.[11] Too much incentive can enrich licensees at the expense of customers and consumers; too little incentive increases appropriation risk and can result in the abandonment of development efforts and the failure to commercialize the technology.

[10]These means, and reasons for choosing among them, will be discussed further in this report.

[11]In patent law, a license is a written authority granted by the owner of a patent to another legal person, empowering the latter to make or use the patented product or process under certain restrictions.

A carefully chosen licensing strategy might increase the probability that an invention will be developed into a commercial product or process. What can the Federal Government do to increase incentives for potential technology partners to take out a license? Additional research support can mitigate technology risk. Federal researchers, along with the OTT, can offer more integrated licensing and research support, perhaps conducting additional testing and extensions of the original research. The original inventor is the most skilled practitioner of the research, and, following mutual agreement, can support product developers with further testing or research. An OTT also may reduce the terms of a technology license, lowering licensing fees.

Sometimes an OTT might opt to attenuate licensee incentives. Since reducing technology risk benefits licensees, the OTT might be able to negotiate more demanding terms in license agreements, for example through higher licensing fees. An OTT might also choose to diversify the technology risk across more than one licensee by choosing nonexclusive licenses, co-exclusive licenses, or licenses exclusive by territory or field of use. Although the definition of these terms often remains loose, nonexclusive licenses[12] are freely granted to as many parties as wish to negotiate them. Co-exclusive licenses may be offered in overlapping fields or territories, but only to a limited number of entities. Licenses exclusive by territory or field of use are issued to different entities in nonoverlapping territories or fields[13] (see box, "Varying Degrees of License Exclusivity").

[12]Nonexclusive licenses are occasionally referred to as "open licenses."

[13]These licenses are occasionally referred to as "multiple exclusive licenses."

Technology development and commercialization can fail for a variety of reasons—lack of financial capital, poorly suited human capital such as a scientific research staff with limited knowledge of the particular area of technology, bad luck, etc.—so a greater number of technology partners might increase the chances that one of them can successfully commercialize the technology. Offsetting this reduction in risk is the greater appropriation risk for licensees when licensing is open to multiple firms. Less exclusive licensing need not exacerbate appropriability risk: a sufficiently profitable market may be able to

Varying Degrees of License Exclusivity

A patent's value stems from its ability to limit competition and thereby increase profits due to the scarcity value of the patented invention. The value of a patent license is therefore related to the extent to which it excludes competitors. Exclusivity is not an absolute, however, but rather exists on a scale. When the Federal Government obtains a patent on its research, it determines the degree of exclusivity in part by how it licenses the patent. Factors such as appropriability risk and market contestability also are relevant to the scarcity value of a technology.

Patent license exclusivity

Exclusivity	Type of license	
Least exclusive	**Publication**	Research is published into the public domain; invention becomes unpatentable and free for anyone to use.
↑	**Nonexclusive licensing**	The Federal Government obtains patent rights, but licenses the patent to any interested party.
	Co-exclusive licensing	The Federal Government obtains patent rights, but offers a limited number of licenses that may be in overlapping fields or territories.
	Licensing exclusive by territory or field of use	The Federal Government obtains patent rights, but offers a set (usually small) limited number of licenses in nonoverlapping territories or fields.
↓	**Sole exclusive licensing**	The Federal Government obtains patent rights, but offers only one license. As in all other cases, the Federal Government retains its own ability to use the invention.
Most exclusive	**No licensing**	Some technologies are not available for license on any terms. Examples include military weapons and nuclear power technology.

Source: ERS analysis.

support numerous licenses. Licensing the same technology to different industries or to different industry segments may create additional markets for a technology and increase its value to society.

Flexible licensing approaches also can reduce risk. For example, high upfront licensing fees or high royalty rates might appear sustainable at early stages of commercialization (see the chapter "Technology Transfer by Federal Agencies"). If the technology reveals itself to be more difficult to develop or the market is less profitable than originally thought, the OTT can revise the terms of a license to maintain technology partner involvement.