Policy Lessons from Technology Transfer Case Studies

Case studies provide an opportunity to observe actions and behaviors. The case studies described in the "Case Studies of ARS Technology Transfer Using Patents" chapter illustrate many of the economic tradeoffs underlying the decisions of technology transfer officers and their licensing partners. These observations permit an economic analysis, which can then be compared with the stated rationales of practitioners from interviews. For instance, some situations call for ARS's OTT to balance policy objectives against the demands of potential licensees, as it does when deciding how many licenses to grant. Open licensing of a technology might be the least restrictive approach to licensing, but potential technology partners sometimes demand an exclusive license to compensate for technology and appropriation risks associated with the project.

Although the case studies provide a wealth of information, interpreting their specific circumstances to arrive at more general conclusions about technology transfer policy poses some problems. One issue is the confidentiality of licensing agreements between the USDA and its technology partners. Licenses contain sensitive business information that might create problems for the licensees if it were divulged: for example, the degree to which any particular licensee is pursuing development of a technology, whether a particular license is generating royalty income for USDA, and if so, the amount of that royalty income.[34] Furthermore, interviews with technology transfer participants were conducted under a pledge of confidentiality to ensure candid observations for the case studies. Preserving the confidentiality of case study information sometimes requires details from the case studies to be omitted from the conclusions presented in this chapter. Where possible, this chapter attempts to support conclusions by presenting them alongside specific facts from relevant case studies.

[34]Knowledge of the terms of the license along with royalty payments also would reveal another confidential item, product sales.

The technology transfer process frequently involves several decisions made simultaneously under tight legal and commercial deadlines. In other cases, the path toward commercialization is indirect and idiosyncratic. This chapter organizes conclusions of economic analysis of the case studies into a sequence that roughly follows a linear model of the technology transfer process, from research to license negotiation to commercialization.

Technology Partners

ARS seeks out a wide variety of technology partners.

The determination of the ARS Patent Review Committee to patent and license a technology is frequently made with a technology partner already in mind, although this is not always the case (e.g., *Bradyrhizobium*). OTT managers spend a significant amount of time performing the critical task of identifying a wide variety of potential licensing partners to find appropriate matches. Choosing from a broad set of licensing partners diversifies technology risk across different companies and industries and increases the likelihood of successful commercialization. The *Cryptosporidium* case is an example of a technology with potential application in multiple markets; pursuing licenses for both veterinary and human pharmaceutical applications provided more opportunities for successful commercialization.

Technology transfer officers have an obvious choice of licensing partner when initial research is conducted under a CRADA. Most of the case study technologies were developed at some point with a CRADA partner.[35] Under the Federal Technology Transfer Act of 1996, CRADA partners have the right of first refusal for an exclusive technology license before a license can be granted to another party.

[35]Although many ARS technologies are now developed with a CRADA, the proportion of licenses to CRADA partners is somewhat smaller because not all of them exercise their licensing option; see the chapter titled "Technology Transfer at the Agricultural Research Service (ARS)."

When technology is developed without a CRADA partner, or after a CRADA partner declines the option to license exclusively, ARS is free to search for other licensing partners. One strategy is to pursue licenses in a niche market. By definition, niche market technologies are served by a small number of firms, in which case the technology itself suggests technology partners. Another strategy is for Federal researchers to explore interest in the relevant field of science for the invention through contacts at research conferences and professional meetings. Both of these strategies for finding technology partners were employed in the eventual licensing of the *Bradyrhizobium* patent.

Industry structure can be an additional guide to possible technology partners. Firms upstream and downstream in the supply chain from a technology partner candidate are also potential licensees. Depending on interactions between suppliers and customers, licensees at different positions in the supply chain might have different incentives for cooperation and technological development.

The feather fiber patent is an example of how this strategy for finding licensing partners can work. ARS reached a licensing agreement with an obvious source of soiled feathers, a large processor of poultry for human consumption. Another license was offered to a firm downstream in the poultry-processing supply chain that processed poultry offal as pet food. A third license was offered to another downstream firm already using feather protein to manufacture nutritional supplements.

License Exclusivity

Multiple licenses address appropriation risk, while exclusive licenses focus on technology risk.

A critical licensing decision for an OTT is the number of licenses it should grant. The agency can grant one license, multiple licenses, or even publish the discovery so that it is freely available to all (see box, "Varying Degrees of License Exclusivity" p. 10). Potential licensees expressed a preference for exclusive licenses to remove one source of appropriation risk: competition from other licensees. Economic theory predicts higher prices and profits when there is only one supplier, explaining this preference. In some cases, expanding the number of co-exclusive licenses may have had the effect of reducing incentives for further product development.

However, under the right market conditions and licensing strategies, multiple co-exclusive license agreements did not pose a barrier to successful technology transfer in some case studies. The advantages of multiple licenses for diversifying technology risk are discussed in the previous section. Another goal of technology transfer is to maximize the use of a technology. In general, suppliers in competitive markets offer lower prices and thus encourage more widespread introduction of the technology adoption. Co-exclusive licenses and other less exclusive licensing agreements increase competitive pressure compared with sole exclusive licenses.

Although it is not possible to generalize the net result of multiple licenses on technology transfer directly from the case studies, it is interesting to consider what might have happened to commercialization of the *Bradyrhizobium* inoculant if both major inoculant suppliers had licensed the patent instead of just one. Would the prospect of competition have undermined investments in development? Or would the competition have driven both competitors to distribute the technology at a lower price to more customers? Another question is whether ARS can adopt licensing policies and practices that influence the outcome, a possibility discussed in subsequent sections of this chapter.

Licensee business plans, market size, profitability, and the availability of substitutes for the invention are some of the relevant factors that determine the degree of exclusivity that potential licensees will accept. For instance, one business plan might involve selling a product or service based on the invention at a small profit margin, but to a large number of customers. In a potentially profitable market where one licensee would have trouble satisfying demand for the product, it appears that additional supply from competitors under co-exclusive licenses did not slow down licensee development efforts. Likewise, where noninfringing substitutes already limit the markup over production costs that a licensee can charge, competition from these substitutes may be more relevant than competition from other licensees that price at a similar markup. An example of a noninfringing substitute from the feather-fiber license is feather meal. The potential use of soiled feathers as feather meal places a lower bound for the profitability of cleaned feathers for other industrial uses. However, if competition with other licensees erodes the already small profit margin, licensees may balk at taking out a license and technology transfer may not occur.

Another licensee business plan might involve selling a product or service based on the invention at a very high price, a strategy that is more likely to succeed when the quantity demanded is relatively unresponsive to price. Charging a high price already limits the number of willing buyers somewhat, but the absence of feasible alternatives might justify high profit margins in this market. This strategy might not be sustainable under co-exclusive licensing. If customers can obtain a close substitute from other licensees, this business plan might not be sufficiently profitable to justify interest in technology transfer. The risks posed by either licensee might cause both to avoid the technology. None of the technologies in the case studies appeared to adopt this strategy for commercialization.

Licensee Characteristics

Technology partners contribute different backgrounds and abilities.

Although there are numerous ways that licensing can work, successful licensees share some common attributes. A certain degree of entrepreneurial energy was necessary for all of the eventual licensees to find out about ARS research and apply for technology licenses. Small startup firms organized around the development and commercialization of a new ARS technology were relatively focused on its development. However, larger and more established firms often proved to be equally aggressive in pursuing licenses and carrying out development.

Each of the licensees required access to financial capital necessary for upfront expenditures on technology development. Sources and cost of that capital were factors in the ability to obtain a license and pursue technology development. When patents, licenses, and other intangible assets represent a significant fraction of a firm's total value, valuation of those intangible assets can affect access to collateralized loans or the terms of additional equity investment. In these cases, licensees cited licenses of patent-protected ARS research as an important factor for raising capital for commercialization investments. Moreover, inability to raise sufficient capital was a constraining factor in several licenses, notwithstanding OTT efforts to screen out undercapitalized firms.

More established firms in our case studies were able to finance their own investments in technology development, through previous issuance of debt or equity or through earnings retained from other operations.[36] While funding from these internal sources might be less expensive, their availability depends on a firm's other resources and investment opportunities. For instance, access to inexpensive capital financing did not guarantee that the company had the managerial time, talent, or complementary assets to carry out a successful technology development program for licensed ARS technology. Other factors were certainly at play, including market demand, technology risk, and the profitability of existing operations or alternative projects.

[36]Debt refers to a liability that must be repaid; interest is usually paid on debt. Equity refers to stock issued by a company.

Industry Experience

Industry experience is another characteristic that can be important. Do licensees have the background and experience to succeed? Firms already familiar with an industry might be better suited to take advantage of a new technology, and might be able to develop technology as an ancillary operation rather than as a central business concept.

From the case studies, a challenge confronting some licensees of the low-phytic-acid maize patent was obtaining a competitive maize hybrid in which to incorporate the low-phytic-acid trait. Since the early embodiments of the technology also had a side effect of reducing yields, placement of the trait in an already high-yielding variety would be an advantage. A company with complementary assets in the form of an existing corn breeding program is likely to face less difficulty meeting this challenge than a company without relevant experience. Similarly, a potential advantage among feather fiber licensees was prior industry experience with efficient disposal of feathers and other poultry processing byproducts. A firm already managing a waste stream of chicken feathers might have greater incentive and aptitude for development of the feather fiber technology.

Company Size

Small and large companies alike can benefit from successful technology transfer. Small businesses like the niche market licensee of the *Bradyrhizobium* patent can be effective competitors, satisfying market demand and successfully moving technology into profitable development. Moreover, license grants to small businesses satisfy the explicit intent of Federal technology transfer legislation. First preference for federally licensed technologies typically goes to businesses with fewer than 500 employees, provided they have equal or greater likelihood of bringing the invention to practical application within a reasonable time (35 USC 209).[37]

[37]The Small Business Administration publishes the Small Business Size Regulations that defines "small businesses" for each industry, based on either number of employees or size of annual revenues.

Licensing Terms

Ex ante *technology assessment*

A challenge to negotiations between licensees and OTT is that the exact size and characteristics of a market are typically not known in advance, or *ex ante*. Until a product is developed and made available for sale, the size and characteristics of a market can only be estimated. Unfortunately, terms of a licensing agreement must be negotiated before technology transfer can move forward or market size can be definitively known. Licensing negotiations must account for differing estimates about the value of the technology, with repercussion on the licensing terms. Negotiations can adjust terms of a license to reflect different views on market size, market characteristics, technology risk, and appropriation risk, but reasonable people can often differ in their assessment of these factors.

Terms of a licensing agreement affect more than the bottom line.

Negotiating license agreements in this environment is therefore a difficult but intrinsic challenge to technology transfer. Flexible licensing approaches, including renegotiation, may be necessary as more is learned about a technology and the market in which the technology is commercialized. Against this flexible approach, technology transfer officers must weigh the need for credible commitments from both sides.

Empirical studies of licensing behaviors show that royalties are used in a majority of licensing agreements, and that agreements often combine license execution fees, milestone payments, and royalties (Taylor and Silberstone, 1973; Rostoker 1984; Macho-Stadler et al., 1996; Basquet 1998; Thursby et al., 2001). The case studies show a similar diversity as to which licensing terms were employed. By tailoring the specificity of performance milestones, the incentives of licensing fees, the risk allocation of royalties, and the degree of competition implied by the number of licenses offered, an OTT can craft a licensing agreement that is appropriate for its technology and acceptable to its technology partners.

Specific Performance Clauses

Licensing terms seek to expedite technology development. One way to achieve this is to require specific goals to be met in a given time period. For example, some licenses required construction of a production facility within a predetermined date after license execution. Specific performance requirements are useful in comparing the measures that different licensees will undertake to develop and commercialize a licensed invention.

Licensing Fees

Licensing fees are a straightforward element of a technology transfer license, involving a transfer of a specific amount of money in exchange for a license to use the technology. License fees are typically payable upon execution of the license.

Another type of licensing fee, sometimes referred to as a "milestone payment," is payable at some point after license execution. Milestone payments can be triggered by an agreed time interval (e.g., 5 years after license execution) or by completion of a specific performance requirement (e.g., completion of a working prototype or production facility). Licensing fees paid upon license execution commit licensee resources to the project, screening out licensees that lack the ability, resources, or motivation to proceed immediately with technology development. In addition, a portion of licensing fees is distributed to ARS inventors, creating incentives both to research patentable technology and to assist in its development.

Jensen and Thursby (2001) found that licensing fees payable at subsequent intervals may prevent "technology shelving," instead prompting licensees to perform the technology development and commercialization efforts necessary to generate an income flow sufficient to meet fee payments. This analysis is consistent with views expressed by case study participants.

Licensing Royalties

Royalties are another way to generate licensing revenue. Royalties stipulate a fee based on sales of products or services based on the licensed invention. Royalty fees assessed as a per unit charge on the licensee have the undesirable effect of increasing the licensee's unit cost of producing and selling the invention, which discourages its widespread use at the margin. Kamien and Tauman (1986) show that fee-only licensing is theoretically superior to royalty-only licensing for patent owners, consumers, and society as a whole, because lump sum fees provide a monetary incentive to inventors, yet lack the price-distorting effect of royalties.

License negotiators can attempt to structure royalties to get around this problem. For instance, royalties based on sale revenues rather than units sold offer an improvement in both licensee profit and consumer benefit for the same amount of royalty revenue (Bousquet et al., 1998). Royalties can also be phased in at specific amounts. For instance, a fixed royalty payable when total sales reach specific increments does not discourage additional sales except very close to the incremental border. Royalty rates can also vary with the amount of sales (so called "nonlinear" royalty rates), which helps to tailor a license agreement to the specific circumstances of the technology. Although ARS used some of these royalty devices, achieving the theoretically optimal licensing structure in general might require an auction process (Kamien, 2002), which is at odds with the actual process of Federal technology transfer.

Despite their drawbacks, royalties can serve several important functions. Licensees confirmed that royalty components of licensing revenue were less risky for licensees than fixed licensing-fee components: under a royalty agreement, licensees did not pay royalties unless the invention overcomes technology and appropriation risks and enters a productive phase of development (Bousquet et al., 1998). In this way, royalties can reduce risk and help overcome the *ex ante* problem discussed above, even if they are less efficient *ex post*.

The economics literature suggests other important functions of royalties, although they might not always apply to Federal technology transfer. If the licensor knows that the technology is likely to be very valuable, reducing upfront licensing fees in exchange for higher royalty payments signals a high value of an invention to the licensee (Gallini and Wright, 1990). Similarly, licensees with an advantage in or knowledge about the downstream market can offer to pay higher royalty payments to separate themselves from other potential licensees (Beggs, 1992). Some of these signaling models are sensitive to assumptions about the number of licensees, the sequence in which license terms are negotiated, and other factors that might conflict with the actual process of technology transfer as governed by Federal guidelines.[38] It is not clear that participants in the case studies explicitly utilized any of these insights from theoretical models of signaling and screening with royalties.

[38]Parties to a transaction may not have the same information. A signaling model is one in which an observed economic action separates individuals or firms into two or more groups and reveals information that was not observable directly before that action.

Royalties are efficient licensing mechanisms in another class of models, in which the licensor competes in the downstream market against licensees. In these models, the licensor profits both from the royalty payments and from raising competitors' marginal costs by the amount of the royalty (Rockett 1990; Kamien and Tauman, 2001). The efficiency of royalties in these models depends on two assumptions, that the licensor competes against the licensees and that the licensor maximizes licensing revenues; neither assumption is likely to apply to Federal technology transfer. With respect to the latter assumption, licensing revenues from fees and royalties are one goal of Federal technology transfer among many, with priority also given to moving technology "off the shelf," addressing market failures, encouraging small businesses, and other goals.

Technology Development Assistance

Sometimes product development requires more research.

Most Federal research requires additional development effort to become a successful product. Although primarily engaged in "basic" research on fundamental science problems with widespread applicability, ARS researchers in our cases also described a role in their jobs for "applied" development geared toward a specific product. This view of ARS scientists in our case study comports with a study by Crow and Bozeman (1998), who found that researchers at Federal laboratories view technology transfer as an important part of their jobs.

It is reasonable to conclude that the same researchers who invent patented research are uniquely well-suited to further development of the technology. Toole and Czarnitzki (2005) explore the role of scientist involvement in commercialization in the Federal Small Business Innovation Research program, and conclude that scientist involvement is an important factor in technology transfer. The case studies in this report exhibit a wide range of perceived and actual behaviors. In at least one case, an ARS scientist performed additional tasks that helped commercialize the resulting invention. In another case, the ARS scientist took a less active role, but still made some suggestions to help guide further research. The case studies also included a situation in which at least one licensee felt that lack of technology development assistance by ARS was a barrier to commercialization that eventually halted technology transfer.

Incentives exist to encourage Federal researchers to provide development assistance to licensing partners. For instance, patents are treated as a publication in performance evaluations of Federal scientists. In keeping with the basic premise of the Stevenson-Wydler Act, scientists also receive a portion of licensing revenues resulting from their research.

However, there are some barriers to additional product-development assistance by Federal laboratories:

(1) Time spent in development is taken from the primary role of researchers, which is to conduct basic research on the next set of problems identified by USDA National Program leaders.

(2) Incentives for the researcher to work on further product development might be limited. Although monetary awards for developers exist, career advancement is primarily measured by the scientific value of research (7 USC 7657). To a lesser extent, this problem exists at the prepatent, basic stage of research as well: although patents are counted as a scientific publication towards annual performance reviews, interviews with ARS inventors suggest that patents are more time-consuming to achieve than journal publications.

(3) Development assistance can set up potential conflicts of interest, especially when a patent has multiple licensees. Assistance rendered to one licensee might harm the competitiveness of the other licensees. Consumer surveys indicate that the Federal Government has a strong reputation for providing science-based, impartial information (Gaskell et al., 1999). USDA interactions require continuing adherence to the mission and core values of research agencies, which could be compromised if the USDA were to be viewed as partial to a particular commercial concern.

License Abandonment

Circumstances might require parties to end their agreement.

For some technologies in our case studies, licensees chose to abandon their licenses. Contributing causes included inability of licensees to secure financing, unforeseen problems with the technology, or other unexpected hurdles that were not apparent at license execution. Some amount of license abandonment is probably inevitable considering the risky nature of technology transfer and commercialization. Subsequent licensing fees (“milestone payments”) may have provoked license termination decisions, because they impose a direct cost for continued lack of success. In some cases, early termination of a license probably represented a more efficient course of action than carrying on unsuccessfully.

License abandonment can be mutually advantageous for both ARS and its licensees. Certainly, it is advantageous for a licensee with an unworkable technology to move on to other endeavors. Abandonment probably reduces OTT administration costs of unsuccessful licenses. Furthermore, in the case of co-exclusive licenses, remaining licensees see their share of the market increase, which increases incentives for additional development. For difficult, expensive, or marginal technologies—the ones most likely to see license abandonment in the first place—licensee exit is a self-equilibrating mechanism to reward successful licensees.

Agency Mission and Licensing Strategy

Successful technoloy transfer finds a balance among several goals and priorities.

Federal technology transfer legislation and USDA technology transfer policy are designed to accomplish many goals, as outlined in chapters 3 and 4. Licensing of USDA technology is only one of several approaches to the fast and widespread dissemination of scientific research.

Even when technology transfer through licensing of Federal technology is an appropriate policy, technology transfer goals must be balanced against broader Federal research goals. Rules aimed at making the technology transfer process fair and transparent illustrate this point. For example, the names of technology partners selected for licenses are required to be published in the Federal Register, at which point other firms can file appeals and seek to obtain licenses themselves (37 CFR 404.7). Although members of the Association of University Technology Managers (AUTM) have policies in place that encourage technology transfer in the public interest, they are largely free from the specific disclosure requirements found in the Code of Federal Regulations. As a result, their licensing behavior is frequently very different than that of Federal OTTs. Greater prevalence of exclusive licenses by universities suggests that Federal technology transfer policies sometimes constrain Federal OTT choices. Process rules are not always the preferred means for technology transfer: the transparency and fairness required of Federal licensing offices is balanced against the potential for an open process to slow down technology transfer in many cases, or to preempt favorable terms for the Federal Government.

Another example of balancing Federal research goals against technology transfer outcomes is the case of “orphan markets.” An orphan market is one in which new and improved products are technologically feasible, but small market demand or limited ability to pay discourages firms from undertaking the risk and expense of R&D. Federal research priorities take into account a wide variety of national research needs, not just potentially lucrative markets. Technology transfer through a licensing agreement with a technology partner might still provide insufficient incentive to encourage supply and adoption of technologies in orphan industries, even if a functional technology is available from a Federal laboratory.

Other Federal goals and policies can weigh heavily on technology transfer outcomes. An example is the development of low-phytic-acid maize developed by USDA/ARS. Low-phytic-acid maize provides a potential environmental benefit by decreasing the amount of phosphorus in agricultural runoff. Standard economic analysis of agricultural runoff suggests that when polluters are not required to internalize the costs of environmental damage, they will have insufficient incentive to adopt a technology that minimizes the environmental costs from runoff. A complementary policy requiring polluters to internalize the cost of phosphorous runoff might create the necessary demand to induce adoption of low-phytic-acid maize. Although designing and implementing complementary policies are far beyond the scope of OTT resources and mission, the existence or lack of complementary policies has an important effect on technology transfer decisions and outcomes.

Despite the limitations of the technology transfer paradigm, a large number of inventions are a good fit with the aims and practices of technology transfer legislation. Furthermore, the OTT does not set the policies and rules under which it operates. Instead, it must pursue its mandate while conforming to those policies and rules.