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Using Technology Absorption as an Evaluation Criterion: Case Studies from a State Research and Development Program

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State agencies sponsoring local research and development projects often finance the development of technologies in partnership with other organizations. These contracting partners develop and demonstrate the new technology. This study distinguishes between two types of outcomes from such projects. Technology absorption is the adoption of a technology by an organization participating in the project. Technology transfer is the process by which outcomes are adopted by organizations outside the project (i.e., nonparticipants). From an evaluation perspective, research and development projects that result in the absorption of technology, without any subsequent transfer, are difficult to assess. Often these outcomes are counted the same as a transfer even though the process is subsidized by the state.

Three case studies of absorption outcomes are presented. Absorption projects tend to be distinctive because: (a) they develop technologies that are very large in scale and very complex; (b) project leadership typically is provided by an end-user who attempts to employ the technology for commercial purposes; (c) success is measured through the technological accomplishment and ongoing commercial venture rather than by the number of adopting organizations; and (d) they produce spillover benefits in the cohesion of the social networks formed among project participants.

Consider the following scenario from an evaluation perspective.[1] An organization enters into an agreement with a state agency whose primary mission is to evaluate and fund research and development (R&D) projects.[2] The resulting project is designed as a demonstration of a technology that the state agency hopes to diffuse to other organizations located within its jurisdiction. The contractor has an interest in adopting the technology for its own use, and will be the site where the project is performed. The work involves the efforts of the contracting organization and of several subcontractors with relevant expertise. The state agency is responsible for funding the work and requires the contractor to locate cofunders for the project. This requirement serves two ends: (a) It assures the agency of the validity and relevance of the project; and (b) it creates other stakeholders through which the project outcomes can be disseminated. At the conclusion of the project, all the participants agree that the demonstration was successful. The contractor adopts the technology and incorporates it into day-to-day operations, but then progress stops. The technology does not transfer to any other organization. A better mousetrap was built, and the world yawned.

What is the state to make of this outcome if the ultimate goal is the diffusion of the technology to constituents? From this perspective the results are ambiguous. The state easily could take one of the following positions, supportable by the literature.

1. Declare a victory. An evaluation might argue easily that this was a tremendously successful project. After all, a technology was demonstrated successfully and transferred to an organization in the state. This view is sensible if the focus of a state agency is on the development of technology rather than dissemination (Bozeman & Fellows, 1988). Under such circumstances the state might evoke, as evidence of effectiveness, economic development indicators such as jobs created, jobs retained, sales growth, or productivity increases (Burton, 1989). Also, the state could take the long view, arguing that R&D projects are mission-oriented (Baer, Johnson, & Merrow, 1976), requiring a great deal of time between the introduction of a technology and any subsequent diffusion.

2. Write the project off as the cost of doing business. The state agency, or, more likely, evaluators from the governor's office or the legislature, just as easily might brand the project a failure because of the lack of a wider diffusion pattern (Atkinson, 1991). The state may be willing to tolerate this expenditure as one of the costs of sponsoring R&D projects. Such endeavors are fraught with uncertainty, so a percentage of project failures are expected. However, state R&D agencies tend to fund projects that are close to commercial application (Lambright & Teich, 1989). Thus, tolerance for this form of experimentation is relatively low.

3. Put things in their proper context. Alternatively, the state agency may argue that we need to understand the specific reasons why the project outputs didn't transfer and how this relates to the local context of potential adopters. The state agency might argue that the route between cause (the project) and effect (benefits to the state) might be an indirect one. For example, the demonstration may have led to the development of an even better mousetrap, or the technology was adapted to an entirely different use.

This scenario is observed in several studies of government agencies sponsoring R&D programs (Gates, 1988; MacDonald, 1986) and across a variety of institutional settings including large national laboratories (Bozeman & Fellows, 1988; Brown, Berry, & Goel, 1991), state projects (Burton, 1989; Forrer, 1989; Lambright & Teich, 1989; Wycoff & Tornatzky, 1988), and international projects (MacDonald, 1986; Supapol, 1990). It also has been observed in different types of projects ranging from demonstrations (Magill & Rogers, 1981) to applied research (Baer et al., 1976; Brown, 1990).

Three case studies of R&D projects, sponsored by the New York State Energy Research and Development Authority (hereafter referred to as the Energy Authority (see Appendix for an overview) are presented here: (a) *Long Island Incinerator Ash;* (b) *Process for the Preparation of Aluminum Nitride;* and (c) *Nassau County Cogeneration.* Each case describes the development of, and consequences from, this scenario, which we call *technology absorption.* Technology absorption is the use of a technology or knowledge developed during a government-sponsored project by a participating contractor, subcontractor, or cosponsor. We argue that it is distinctive from *technology transfer,* which we define as the use by an external organization of technology or technical information developed by project participants. The two processes are, obviously, not independent of one another. Thus, the scenario we described at the beginning of this paper is one where there is absorption of technology but no corresponding transfer.

The three cases are drawn from a larger collection of 31 case studies prepared for the Energy Authority in one of the largest and most exhaustive evaluations of a state R&D agency conducted to date (Bozeman and Associates, 1992; Kingsley & Bozeman, 1997; Kingsley, Bozeman, & Coker, 1996). In roughly one-third of the 31 case studies, this scenario was confronted. The three case studies selected are representative of this subset of project outcomes.

The challenge posed to agencies by projects resulting solely in technology absorption is identifying the value to the state from subsidizing local innovation projects. The value associated with absorption will not be measurable by diffusion standards and may not be measurable by economic development standards. However, in this paper we attempt to articulate the value of absorption projects in terms of improving the local capacity for innovation and competitiveness. To accomplish this task we employ a research technique called *R&D Value Mapping* (RVM) to facilitate the multiple case analysis (Bozeman & Kingsley, 1997; Kingsley et al., 1996).

Technology Absorption as an R&D Project Impact

Absorption projects can pose a problem for state agencies. As a general rule, outcomes from R&D projects are poorly identified (Supapol, 1990; Zhao & Reisman, 1992).[3] Measures of project outcomes often are limited to nominal classifications (Kingsley, 1993; Supapol, 1990), which frequently lump absorption outcomes and transfers of technology together. Evaluations often count adoption of a technology by a project participant as one transfer, qualitatively linking adoption from any source. This overestimates the attractiveness of the technology. The absorption process subsidizes a firm's exploration of a technology, reducing the uncertainty associated with adoption. Such subsidies do not exist in the adoption decision of those not party to the project. The factors that contribute to a transfer outcome are not the same as those that contribute to an absorption outcome (Kingsley et al., 1996).

But making a clear distinction between absorption and transfer outcomes raises a second problem. Absorption projects are perceived as at best an intermediate outcome and at worst a failure by the political bodies that govern the agency. Absorption outcomes seldom produce dramatic outcomes in terms of employment or economic growth, and they count as only one well-subsidized adoption in measures of technology diffusion. Therefore, they leave the agency vulnerable to the charge of providing anecdotal evidence of success.[4]

Consequently, an interesting issue is understanding the grounds on which a government agency supports an absorption outcome. If absorption and transfer arise from different sources (Kingsley et al., 1996), the outcomes may have to be evaluated differently to avoid understating the importance of the technology. Recent developments in theories of economics, sociology, and science and technology policy suggest several alternative rationales. These theories describe factors that do not constitute a market failure but nonetheless may affect local or regional competitiveness.

First, Romer (1986, 1989, 1990) describes how the exchange of ideas among agents can increase dramatically the rate of productivity. In some of his empirical investigations, the rate is so tremendous that as local economies increase the scale of their operations, the increase in output more than doubles. For example, two programmers accomplish more than twice that of a single programmer because they can consult each other directly. Link and Bauer (1989) make a similar point in estimating that the rate of return on investments in R&D for manufacturing firms participating in cooperative R&D programs was roughly 150% higher than for nonparticipating firms.

This literature dovetails into another development in trade theory. Krugman (1980, 1991, 1994) argues that production cost advantages may accrue to a particular region that defines a large market for a product. That enormous local product demand justifies an ever-larger scale of operation of economic enterprises. If competitive trade suddenly emerges between firms from a large local market and firms in a small one, the larger scale of firms in the larger market instantly would dominate. If scale differences were severe enough to resist entry into the fixed capital adjustments needed to "catch up," then that advantage might be permanent.[5] Firms clearly understand the danger. Cohen and Levinthal (1989) found that nearly half of industry R&D is designed, in fact, to keep abreast of advances in the potential market applications of technology.

Linking up the arguments of Romer and Krugman, the external capital outside the firm might be human capital as well. The external human capital includes local bankers familiar with the particular industry, local contractors specialized with the particular plant design, vocational schools producing graduates targeted to local industry, service organizations such as the chamber of commerce or extension, or even local policemen, zoning officials, and health regulators familiar with the process of the firm's activities. These are precisely the types of services surrounding the use of an innovation that leads Granovetter (1985) to describe technologies as "embedded" in a larger social system. All of these external investments augment the capital scale of the firm and help to lower its marginal production costs—often substantially.

In a given location, finding oneself in a physical scale deficiency and outside the discourse center creates a constellation of effects that can spiral into complete eradication of the industry from the local area within a very short period of time. Though physical location may be unnecessary for participation in the creative industry dialogue, the positive physical and human capital externalities do act in concert. Having the technology in hand admits one into the learning-by-doing exchanges. Absent this opportunity, one can lose ground very quickly. Romer (1986, 1989, 1990), Krugman (1980, 1991, 1994) and Granovetter (1985) each suggest separately that when there are increasing returns to scale from physical and human capital applications, a small and potentially correctable shortfall can deteriorate rapidly into wholly noncompetitive local industry.

Watkins (1991) extends this argument in finding that when communication costs and learning costs are high, as they often are with technological innovations, free-market structures are not well suited to minimizing them. Thus, not only does an area require a sufficient level of technological, organizational, and economic capacity for adoption of an innovation, but there also need to be established patterns of communication among these resources that facilitate "taking in, adopting, improving, and making a technology part of a firm or nation's existing base of technical knowledge" (Watkins, 1991, p. 92).

By treating R&D as an impure public good, Watkins finds that a market failure framework is not enough for policymakers because it does not account for the positive role governments can play by helping firms overcome social and political barriers to negotiations and the costs of technological communications. As impure public goods, R&D outputs suffer from degrees of indivisibility and congestion, where the size of the group receiving spillover benefits is a critical issue. For some technologies, the larger the number of organizations that have access, the less the return. The impurity of R&D as a public good implies that there should not be a single government policy, but rather a portfolio of tools available dependent upon the technology and the environment. For complex technologies, the number that have an interest in innovating, have the capacity to understand the technology, and can garner necessary complementary assets to secure benefits from the innovation will be much smaller. Yet the ripple effects of a technological adoption by a single healthy actor in a technologically driven industry can be profound.

These developments in the literature suggest several alternative rationales that may be used in supporting an absorption project: (a) overcoming human capital shortfalls by stimulating cooperation among organizations, (b) overcoming technological shortfalls that may lead to the eradication of a local firm or industry, and (c) subsidizing the costs of communication of technological information and learning exchanges. In this study, each absorption case is examined from the perspective of these rationales.

Case Studies of Technology Absorption

The three case studies presented here were developed during a larger evaluation of the Energy Authority using an RVM method (for a complete explanation of this method see Bozeman & Kingsley, 1997). RVM begins with one or more analytical models specifying the possible outcomes of R&D projects. These models organize the sequence of events into a branching structure that ultimately may lead to an outcome. In the Energy Authority cases two models were applied—one for a technology transfer outcome and one for a technology absorption outcome (Kingsley et al., 1996).

A typology resulted from this assessment of the projects.[6,7] The other categories of cases fall within existing expectations for R&D projects as either having wider diffusion or failing to transfer. However, the absorption cases are anomalous because the technology was adopted only by organizations participating in the project. Clearly, benefits accrued to the absorbing organization, but managers at the Energy Authority also felt that these were very successful projects from the perspective of the state.

The three cases presented below are representative of the range of behaviors and outcomes found within the absorption category.[8] They reflect the variety of interactions between public and private sector organizations that were observed in the absorption projects.[9] Consequently, the value that projects added flowed through the actions of the state, the marketplace, or both. Similarly, the recipient of the value added might range from a single firm to the entire state.

Case 1: Long Island Incinerator Ash

The goal of the Long Island Incinerator Ash project was to find a practical use for ash residue from municipal waste burning facilities. This ash residue quickly is becoming a major solid waste disposal problem for the municipalities in the region. Waste collection and disposal had become one of the largest, if not the largest, item in the budgets of several towns on Long Island. In some cases, over 40% of the budget went to waste disposal. Efforts to create a regional landfill for ash (through the Regional Ash Fill Law) were thwarted through intense political pressure from community NIMBY[10] groups and environmental interest groups. This left many state and local governments at a loss as to how to develop a solution for the disposal of ash residue. The project intended to provide a technological alternative to waste disposal that is safe, permanent, and economical.

The problem is of sufficient magnitude that the project attracted participation from more than 20 government entities, including state agencies from New Jersey and New York, regional planning boards and authorities, New York City government, and many small towns and villages on Long Island. The Energy Authority's request for proposals had acted as a catalyst bringing these governmental groups together with technical expertise from the private sector and from the universities. Over $4 million was dedicated to several demonstrations of the use of ash in the roads and highways within the region. The Energy Authority was the largest single sponsor, providing slightly over $1.7 million. Thus, one of the other primary goals of the project was to assess the effectiveness of interorganizational and intergovernmental efforts to address the ash residue problem. According to one Port Authority of New York and New Jersey official:

> ... [the project is] not just physical tests of the material but involves establishing an institutional and regulatory framework by which applications can be developed now, and then replicated on a commercial scale. If this cannot be done, then the project will be a waste of time [producing] lots of information and data that won't mean anything.

A great deal of time and effort was required in creating the alliance of project participants. Issues of procedure and trust had to be overcome. For example, it took more than a year (from 1988 to 1989) to develop sufficient support in the Port Authority to get a cofunding commitment of $500,000. Most Port Authority project funding is not via grants and contracts, but as capital investment. Since the Port Authority has no taxing ability, almost all of its projects require a return on investment. Ultimately, the clear need for a regional solution to the ash disposal problem and the emergence of a regional coalition to address the issue persuaded the Port Authority to waive the usual operating procedures.

In the same vein, key players within the Long Island Regional Planning Board (LIRPB) were reluctant to enter into an agreement with the Energy Authority. Their previous experience in working with a grant from the Energy Authority had left a sour taste for collaboration. However, other voices within the LIRPB, who saw the Energy Authority solicitation as this timely "hand [that] came down from Albany," set the course of action.

A great deal of learning-by-doing was required to make this large-scale, multiactor project successful. In particular, the technical people and the contract people had to work out their different approaches to doing business. The technical people recognized that the size of this project demanded some fluidity in defining the tasks that needed to be performed so that project participants could apply their learning to the project. This required the contract people to build in similar flexibility.

> With this project, we could change the contract once a week, but we would do nothing but write contract modifications.... With so many agencies making decisions as one goes, the project is planned almost while you are implementing it. For example, maybe you decide that you want to look at certain tests, and then new information comes in and you no longer need the tests. With a four year project you can't put blinders on and assume the rest of the world doesn't change. You need to recognize change. But there are always contract and budget implications of change.

This project resulted in several demonstrations of the use of ash, particularly in roads, that continue to be used by participating governments. Absorption has occurred through the use of ash as a partial aggregate for asphalt and as a material for landfill construction projects. Although many participants still anticipate technology transfer from the project, none had occurred at the time of case writing. The definition of a successful transfer in this case is that a community (other than those participating) adopts technologies for the reuse of ash in road and construction projects.

However, there already have been major benefits to the state. The Long Island case illustrates the different ways in which value can be added in through absorption of a technology by the public sector. First, the project has stimulated New York's Department of Environmental Conservation to develop regulations on the beneficial use of ash. Previously, beneficial reuse of ash was not even a part of their vocabulary. Second, the project has heightened the awareness of state agencies and municipalities concerning ash. For example, in learning about the reuse of ash, several towns also learned of ways to improve incineration practices reducing the production of ash. Third, the project has created a working alliance among government entities that has been extended to addressing issues other than ash. The incentive driving many of the participants was recognition that the environmental problems they confronted could best be approached through regional solutions. The project has been helpful in forging such cooperative linkages.

Case 2: Nassau County Cogeneration

The Nassau County project resulted in the only instance of a successful privatization of public utility cogeneration in New York. The project's purpose was to construct and begin to operate a cogeneration plant that would provide energy to the Nassau County Medical Center, the Nassau County jail, and later a number of other institutions. The county was dissatisfied with the underutilization of the existing district heating and cooling system that had been built in the 1960s. The system, which cost $6 million to create and required $3 million annually to operate, was operating at only 20% of capacity. Rather than seek a simple technology fix, the county sought out expertise in the operation and maintenance of cogeneration plants from the private sector. The chief objective was developing a system with no output of tax revenues.

The Energy Authority has long supported the improvement of old district heating systems. However, this project specifically was to assist in completing the design, marketing, environmental, legal, and financial analysis to secure approval for acquiring the needed human capital through privatization. The Authority provided a grant of $373,000 to the county. The overall project, including private sector investment, cost $60,373,000. To achieve this end, the project required exploring uncharted territory. This project initiated a great deal of learning in the complexities of acquiring licenses and permissions, negotiating with the local public utility and the Public Service Commission (PSC), and in creating contracts with the county. The lessons from this case are not so much about the role of private entrepreneurs in public utility cogeneration as about the difficulties in implementing a large-scale energy innovation in an unaccommodating political, regulatory, and legal environment.

The chief problems encountered occurred prior to construction and operation. A series of groups raised objections to the project over the following: (a) the amount of noise that would be created, (b) the perception that this would be a giveaway of county facilities to the private sector, (c) pollution and falling property values, (d) partisan politics within the county, and (e) the job security of the operators' union that worked on the old district heating system. Each of these groups and their objections had to be addressed in crafting the privatization contract.

More troublesome were the negotiations with the Public Service Commission and with the local electric utility. According to one county executive:

> The co-generator is always more efficient at converting fuel than utilities are, but their energy is cheaper than ours. The co-generator must deal with the utilities' own calculations of cost, the utilities' profit on gas and electricity provided, high transport costs for small distances, and penalties for not maintaining a minimum level of use. When one adds to this the level of risk borne by the co-generator, the uncertainty caused by a changing regulatory environment, and clear differences in fixed costs, it becomes clear that the entrepreneurial incentives are not likely to be sufficient in many cases to encourage more co-generators to enter the marketplace.

The new, privatized system went on-line March 27, 1991, under the management of the Trigen Energy Corporation. Trigen was able to persevere in this hostile environment by forging a close working relationship with Nassau County. Collectively, they were able to navigate a course through several barriers at the state and local levels. From a broader perspective, the many headaches suffered by Trigen can be seen as a special kind of social learning with significant positive spillover effects. Communication barriers were encountered in efforts to persuade the community that the project was not a boondoggle, nor would it adversely affect the environment. Human capital barriers were encountered in the inexperience of the PSC with privatization initiatives and in the utility's resistance to cogeneration. While it may be naive to suggest that the Trigen experience will smooth the path for future privatizations, at least the trail has been blazed and some of the hazards marked. While the Energy Authority describes the goal of the Nassau County project in terms of technology, it appears that it was designed to achieve an absorption outcome: The prime audience includes the developer [Trigen], Nassau County, other district heating customers, and LILCO ratepayers. Technology transfer to this audience is inherent to the project.[11]

By "inherent" the Energy Authority means that the transfer flows from the creation and use of the technology by Trigen in serving its customer base. This definition of transfer makes it difficult to distinguish between the direct benefits and the target audience for the project, and the indirect benefits and the secondary or tertiary audience. In fact, the above statement is testimony to the fact that the Energy Authority will include some notion of technology absorption in its definition of technology transfer.

Case 3: Process for Preparation of Aluminum Nitride

The political rhetoric justifying state-sponsored R&D projects is usually peppered with references to enhancing the competitiveness of industry within the state. While the first two projects do not fit such a mold, the third is very much in this tradition. In the Aluminum Nitride case the time and talents of researchers from Clarkson University, a state-funded university, are focused on the needs of a local firm in the ceramics industry, Advanced Refractory Technologies, Inc. (ART). The research was performed through the auspices of the Center for Advanced Materials Processing (CAMP) at Clarkson. The researchers at CAMP had invested several years in introducing the capabilities of the center to the ceramics industry in the State of New York. Comparatively, the project was small, requiring a $90,000 grant from the Energy Authority to leverage funds for a $118,105 project budget.

The industry-university partnership investigated a polymer coating technology for aluminum nitride (Al_2N_2) powders to improve handling and processing. Al_2N_2 is a relatively new ceramic engineering material that has high thermal conductivity and corrosion resistance. When used to form molded parts in energy-using equipment, Al_2N_2 offers significant improvements in energy conversion efficiencies. A considerable market for this material could develop in computer chips and molded parts for airplanes, boat engines, pumps, and cutting tools.

However, Al_2N_2 ceramic powders have been vulnerable to contamination by water vapor from the atmosphere (hydrolysis), which degrades performance in the molded parts. Current remedies use organic solvents, which are environmentally unsound, must be recycled, and require high energy costs to do so. This project successfully developed a means of coating Al_2N_2 powder to inhibit contamination using an organic polymer that is applied through an aerosol reaction technology. This success allows the ceramic powder to be stored in inventory, and makes the manufacturing process more economical and energy-efficient.

Probably the single most important scientific finding was that specific organic chemicals chemisorb with the surface of Al_2N_2, a process without which polymer coating could not have been achieved. Indeed, the chemistry behind the coating technology is unique enough to be patentable. However, the technology had not transferred at the time of the case writing either through the sale of coated ceramic powder or through the diffusion of coating technology. The major obstacles are: (a) the inability of ART to convince current users of Al_2N_2 that they can use their old production processes and convert to the use of the new technology, and (b) the inability of university researchers to publish findings because of constraints the company faces in the patenting process. The ceramic materials market has a 3 to 4-year turnaround time. ART is now trying to position Al_2N_2 to take advantage of the next market cycle.

The custom-made innovation of the production technology in the Aluminum Nitride project admits no obvious immediate transfer. The local ceramics firm is uniquely capitalized (scaled) to fit local producers, and the production technology is fitted to that enterprise. It is unlikely that any other firm would be interested in the exact technical dimensions of the developments generated by the project. So, far from being an expansive project, the production technology benefits almost surely are restricted to one firm. At the close of the case study, the Clarkson research team was performing a follow-up project, funded by the private sector, to create a production technology more amenable to transfer.

While the Aluminum Nitride project does not transfer the technology, it does reinforce and clarify the position of the local ceramics industry vis-a-vis other competing production centers. The unique and strategic position of native enterprises becomes understood and appreciated better by all private, local enterprises. The project goal clearly is to retain the competitiveness of this firm for the purpose of strengthening the position of the entire local industry generally. This goal is accomplished through a retention and expansion of the active local human capital needed to sharpen the on-going evolution and adaptability of that local industry. An example was seen in the project with the hiring of a postdoctoral researcher and graduate students to conduct the work. Stimulating local innovation and cross-industry communication is still a technical benefit. It is a logical corollary to technology transfer; but the focus is on industry innovativeness generally, not technology-specific transfer.

Discussion

The case studies suggest support for a technology absorption project. Clearly, technology absorption is considered a successful outcome in each of the three projects. While there are participants who would wish for a greater diffusion of the technology, this did not dampen a sense of accomplishment in demonstrating the effectiveness of the technology in answering project objectives. Also, participants in these case studies often count technology absorption as a transfer of technology. This was most strongly evident in the Nassau County case, where the transfer objectives were in actuality an absorption outcome. But, as was noted earlier, equating a subsidized adoption process, i.e., absorption, with an unsubsidized process, i.e., transfer, is problematic from an evaluation perspective. By not accounting for absorption outcomes, an agency easily can overestimate the attractiveness of a technology to its constituent industries.

A more accurate evaluation of a technology absorption project would assess the benefits to the project participants and the spillover benefits from performing the project. Examples of spillover benefits were in evidence in each of the cases, where projects were used to remedy missing links in the chain of human resources that had inhibited the application of more efficient technologies. In more than one of the absorption cases the project was used to facilitate the learning not only of the contractor, but also of an entire community of organizations involved in the operation of the technology. The resulting network of relationships also seemed to have a life that extended beyond the specific project. Efforts that identify and update the array of services available locally have been shown to generate profitable connections in the short term (Morse, 1990).[12] This is not to argue that other types of case outcomes, including projects where technology is neither transferred nor absorbed, don't have spillover benefits, but the relationship between the success of the technological demonstration and the staying power of the resulting social networks is an area in need of further research.

Clearly, threats to local competitiveness are a significant element of the project selection strategies of the Energy Authority. The Energy Authority R&D projects underscore the potential gains from strengthening the competitiveness and/or innovativeness of the human capital mix in the local area. This implicit coordination between the public and private sectors becomes important when local organizations face the decision to replace equipment and adopt the next generation of installed capital for their long-term strategy. In a world with dizzying capital mobility and market accessibility, the pressures for regional organizations to keep pace can be severe. However, specific firms and jurisdictions may trip over the particular technological adaptations. Whether they consider the local resources available as emerging from a productive, vibrant local industry will determine the investment decisions of firms and how well their operations will be scaled to fit into that community.

Systematic market assessments to identify areas of capital shortfalls (either physical or human) and barriers to information flows are not a part of the day-to-day responsibilities of the Energy Authority. This is not unique to the Authority. States generally lack the information base and resources for such market assessments (Burton, 1989), suggesting that such strategic R&D efforts are not operational. However, in these cases the targeting of R&D resources emerges through social processes involving strategic planning meetings with government and industry leaders as well as other R&D providers. Technological shortfalls also are identified through the opportunities that come through the door in the form of project proposals. This strategic planning process sets the bounds used by the Energy Authority in identifying "good" projects that will have a useful application. At this point, the degree to which this social process is effective in keeping states from devoting resources to projects that the private sector would cover under any circumstance is unknown.

From an evaluation perspective, these case studies also illustrate the types of barriers to technology transfer evident in the structure of absorption projects. First, these are projects in which end-users of the technology are in a leadership role. Often the gains from the technology provide a competitive advantage to their business. There are few incentives for them to broadcast the means of their success. This was particularly in evidence in the Aluminum Nitride case. Even where end-users are amenable to being advocates for a technology, the experience quickly can become an expensive diversion of time, resources, and effort. Second, the scale of these technologies is very large and complex. Theories of competitiveness suggest that problems of congestion may inhibit firms from adopting large-scale, complex technology (Watkins, 1991). But Energy Authority projects regularly attempt to address a local problem and encourage transfers of the results. However, firms that choose to follow down the same path often do so without the margin for error that the state R&D grant provided. Third, several market barriers were encountered during the course of these cases. This limited the advocates for transfer, in most cases, to third parties, i.e., not a user or producer of the technology. In the Energy Authority cases it was found that if the primary advocate for a technology was a third party, the likelihood of transfer was almost zero. Since state managers know the types of firms that make up a project and the scale of the technology at the outset of a project, these findings may offer a useful heuristic in project selection.

Absorption projects are an important tool for introducing and adapting technologies to regional and local economies. In part, this is due to the complexity of the issues confronting industry. Innovation decisions by firms rarely encounter a simple physical or human capital shortfall in an adoption decision. Rather, these barriers tend to work in tandem. The genesis for the conditions that establish the need for a technological infusion rests in the competitive mechanics of the industry and the nature of the technology that constrains producers in that industry. The problem emerges from a rather exacting investment problem; so the solution mandates a comparatively exacting response. In these instances, the state R&D agency may constitute the only available expertise to appraise the credit worthiness of the investment. By awarding a grant, the agency signals to the larger community that this technology is worth exploring. Correspondingly, the benefits produced in most of these projects extended far beyond the bounds of the individual firm, updating the skills of the entire social network in which the technology is embedded.

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Notes

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[1] This scenario is based upon observed outcomes from R&D projects sponsored by the New York State Energy Research and Development Authority.

[2] The use of the term "organization" is deliberate, signaling that the contractor could be a public, private, or not-for-profit organization.

[3] Reisman and Zhao (1991, p. 38) generalize this bleak assessment in their review of technology transfer research: "There has been no general model or structure for the field; people have merely strung information and insight on an invisible thread and hoped that the thread would continue to hold." In fact, knowledge of interaction between the public and private sectors with regards to technology transfer is primarily descriptive. We know much more about the sequence of events from ideation to commercialization than the critical factors that determine such outcomes (Crow, 1989).

[4] In fact, one of the motivations for the Energy Authority to support the larger study from which this research project is drawn was in an effort to understand the impacts of projects on those who are not project participants.

[5] A rational explanation of the persistence of scale differences in otherwise competitive industries is that they emerge from fixed assets outside the control for the firm that nevertheless support the scale of the firm's activities.

[6] Each point in the models represents a different stage in the absorption and transfer process. The critical point used in creating the typology was whether evidence was offered in the case study that the technology was utilized by either a project participant (absorption) and/or nonparticipant (transfer). Several assumptions underlay these models: (a) Embodied technology and scientific or technical knowledge are routed through the same processes and judged by the same criteria. Hence, trade or professional publications are rated in the same manner as a physical technology. (b) It is not assumed that technology is always advantageous. The models track how the processes of absorption or transfer progressed without assigning positive or negative attributes to the nature of the impacts and have a common potential endpoint for both benefit and disbenefit. (c) Similarly, it is not assumed that progress along either process or both processes constitutes a model for assessing success. Success is contingent upon the goals for the project. A project might be quite successful in achieving the purposes for which it is designed and not proceed along the absorption or transfer model. (d) The models do not propose that technology transfer and absorption follow a linear progression. In any given case, stages might occur out of the sequence provided in the scale. Many points along the model can form feedback loops. This would be the case when there is a renewal of funding before potential adopters receive technology from the first phase of a project.

[7] Twelve of the 31 cases failed to be either absorbed or transferred, and were classified as going on-the-shelf. Eight of the cases exhibited absorption but no transfer outcomes. Four of the cases that were transferred but not absorbed were classified as market-induced. Seven of the cases were both absorbed and transferred, exhibiting a pattern of strong contractor or sponsor promotion and inducement in the process.

[8] The Energy Authority case studies were developed by different case writers to avoid common author bias. The three cases used in this study were written by different authors. However, to ensure comparability, all authors worked with the same research protocols and followed a similar format.

[9] Absorption projects had the greatest diversity of interactions of any category of cases in the Energy Authority study.

[10] NIMBY means "not-in-my-backyard."

[11] From a memorandum to the Technical Review Committee dated December 22, 1986.

[12] For example, geographers have long noted agglomeration effects stemming from the special existing mix of local resources and regulations. Similarly, concerns that regional employment remains stable have been found to motivate training efforts. It also may translate into the mainstay investment subsidies such as deferred taxes and reduced-interest development bonds typical of local development efforts. Though each effects a particular factor of production deemed most needed (labor or capital), all are somewhat nonspecific cost-reducing benefits to a firm. Yet the particular development concerns herein emerge from a new source, and the role is quite specific.

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Appendix

The Case of the Energy Authority: An Overview

The Energy Authority is one of the many state agencies established in response to the energy crises of the 1970s and 1980s. The State of New York was (and remains) particularly vulnerable to such shocks, as it imports over 90% of the state energy supply, 50% in the form of petroleum from suppliers outside the United States (New York State Energy Research and Development Authority, 1983, 1990). Consequently, the Energy Authority funds R&D projects as a means of advancing the use of a wide variety of energy conservation technologies.

In Fiscal Year 1992, the Energy Authority provided more than $13 million for R&D contracts. Typically, in any one year, the Energy Authority sponsors more than 300 projects with contracts ranging from just a few thousand dollars to more than $1 million. The average funding level is about $200,000.

Technology transfer has the odd status of being an important but poorly defined goal for Energy Authority managers. As projects are conducted on a contractual basis, a key criterion of success for project managers is the expenditure of funds in R&D projects to targeted program areas. The vast majority of the project managers' time is spent in the development, review, and contracting of projects. Generally, the project managers simply do not have enough time to be involved actively in technology transfer for all their projects. Those strongly oriented to technology transfer seemed, at least according to interview results (Bozeman & Coker, 1992; Bozeman & Crow, 1991), to do so either because they felt personal pride in the outcome or because they were oriented to external and professional networks where the perception of technology transfer expertise and accomplishment would be viewed favorably.

Another key indicator of success is the amount of cofunding a project receives from other research-sponsoring organizations and project participants. The commitment of cofunds is considered an indicator of the strength of interest for the technology in the market and of participant willingness to develop and/or promote the technology (New York State Energy Research and Development Authority, 1983). In the 31 cases, $10,235,517 of Energy Authority resources leveraged $20,138,067 in cofunds (not including the outlier—the Nassau County case).

As a consequence, great emphasis is given to the "front end" of projects, i.e., the expenditure of Authority funds through the development and approval of R&D projects. A common belief among Energy Authority managers is that the achievement of transfers is best served by selecting "good" projects. Managers apply seven criteria in the selection of projects to sponsor:

1. Contribution to achieving state energy policy goals
2. Potential energy benefits
3. Technical and engineering feasibility
4. Potential economic benefit to the consumers and businesses of the state
5. Potential environmental consequences
6. Relationship to other R&D programs in the state
7. Relationship to other Energy Authority projects and staff capabilities

Several managers suggested that at a more fundamental level a project is considered good at the Authority if it produces something that is useful to the constituents of the State of New York. Evidence of the utility of a project is demonstrated through leveraging additional funds, the potential for technology transfer, and opportunities for recoupment. The majority of the Authority's efforts to achieve transfers have revolved around developing procedures to select "good" projects.

As the fortunes of the energy markets have ebbed and flowed, so, too, has public demand for the development of energy conservation technologies. Adaptations to changed environments have led to more than one reorganization of the program areas funded by the Energy Authority. Though improving energy efficiency is the core theme to projects, in recent years economic development and environmental conservation issues have served as rationales for funding projects.