Technology transfer from U.S. government and university R&D laboratories

Barry Bozeman
Technology and Information Policy Program, Syracuse University, Syracuse, NY 13244 (U.S.A.)

Michael Crow
Office of Science and Technology Policy, Iowa State University and Ames Laboratory, Ames IA 50011 (U.S.A.)

Abstract

Despite the increased interest in domestic technology transfer, there is surprisingly little empirical evidence on determinants of technology transfer activity. This study presents results from a national survey of more than 900 laboratories, focusing on a sub-sample of 134 government laboratories and 139 university laboratories. An environmental dependence model of technology transfer activity is presented, arguing that influence of political authority is a major determinant of technology transfer activity. Tests of the model indicated that scientific and technical mission diversity is particularly important in understanding technology transfer to both government and industry. However, a variety of measures of political boundary spanning are quite important in transfer to government but not so to industry. Likewise, the nature of the resource base (government vs. industrial) is strongly related to the choice to transfer technology to, respectively, government and industry.

1. Introduction

Technology transfer no longer is the exclusive province of individual organizations shopping around for ideas and tools originated elsewhere. Recently, technology transfer has come to be viewed as a critical public policy issue, one so important that nations' innovation rates, economies and very standards of living may hang in the balance. In the United States, one result of this new emphasis on domestic technology transfer is an intense public dialogue, another is an outpouring, since 1980, of new public policy measures aimed at promoting technology transfer. These policy initiatives are wide ranging and include relaxation of anti-trust guidelines, promotion of cooperative research and development (R&D), and mandated involvement of governmental laboratories in technology transfer.
Despite the increased interest in domestic technology transfer, there is surprisingly little empirical evidence on determinants of technology transfer activity. Several case studies have been provided and anecdotes are pervasive, but systematic analyses based on large samples of R&D laboratories are in short supply. The purpose of this study is to provide such an analysis. The study presents results from a national survey of more than 900 laboratories, focusing on a sub-sample of 134 government laboratories and 139 university laboratories. An environmental dependence model of technology transfer activity is presented, arguing that influence of political authority is a major determinant of technology transfer activity.

1.1. Explaining technology transfer: an environmental dependence model

One difficulty in the study of technology transfer is its multiple meanings. Some define technology transfer in the broadest sense to include virtually any movement of knowledge or tools from one organizational or institutional context to another [1], whereas others provide a more restrictive definition requiring a physical embodiment in the form of a product or prototype [2]. The concept (and measure) used here is between the broadest and narrowest definitions. We seek to embrace a variety of knowledge development and utilization activities under the concept of technology transfer but, at the same time, to distinguish clearly technology transfer from basic research and pre-commercial applied research. Thus, we define technology transfer as “the transfer of physical devices, processes, ‘know-how’, or proprietary information about devices or processes from one organization or institution to another” [1]. It should be noted that this definition excludes traditional open literature communication of research in scientific journals and that it requires an organizational context rather than communication solely between private individuals.

The explanation of technology transfer activity has been as problematic as its conceptualization. The dominant explanations have been rooted in economic theory. Production function models provide explanations of the contribution of technical knowledge to economic growth, microeconomic models of firm behavior seek to account for the amount and composition of producers’ R&D, and models rooted in economic history give interpretations of the genesis and flow of technologies. These and other such economic approaches have provided useful and sometimes powerful explanations of behavior surrounding the production and distribution of scientific and technical goods. However, each approach suffers, to a greater or lesser extent, from an inherent weakness—exclusive or nearly exclusive attention to forces emanating from market environments. If aspects of non-market and political environments are examined at all, it is through the lens of market-oriented concepts (e.g. a public good as one for which user charges cannot be efficiently collected).

For a number of reasons, it is necessary to supplement theories of technical change focusing exclusively on market-based or market borrowed concepts. First, and most obvious, many of the producers of technical knowledge are government and university R&D laboratories, for whom traditional market assumptions may be inappropriate. The great majority of studies in R&D economics focus on private R&D laboratories, but private sector laboratories do not produce the preponderance of technical knowledge and produce a small share of some technical goods, including, for example, pre-commercial applied research. Likewise, while one might expect economic models to account for technology transfer to commercial enterprises, one might expect less success from these same models in predicting technology transfer to government.

A less obvious, but perhaps even more compelling, reason to supplement economic models is that the environment of producers of
Technology transfer from U.S. R&D laboratories

Technical knowledge does not so clearly cut along sector lines as it once did. The emergence of new organizational forms, not wholly private and not wholly public, is one factor. One recent study [3] indicated that as many as 25% of R&D units focusing on energy technology could not be meaningfully classified as either government or industry. Likewise, 'sector blurring' has been promoted by the increasing reliance of R&D laboratories of all types on government funding and, at the same time, policies (such as those discussed above) moving government and university laboratories toward commercial activities.

1.2. An environmental interpretation of technology transfer

Recently there has been a growth of interest in environmental interpretations of a wide range of organization behaviors. While some recent efforts have originated in Schumpeterian approaches to the economics of technical change, most of the work seeking to provide environmental interpretations has been advanced outside economics. One stream of relevant work has viewed organizations from an 'ecological' perspective. These studies [4] have employed analogies from biological theories of natural selection to identify the ways in which processes of organizational variation, selection and retention influence changes in organization structures and behaviors, including organization innovation [5].

One of the most important lessons of the ecological environmental models is that organizations respond to a wide variety of environmental stimuli, and market factors are not always the most critical determinants of technology transfer activity. Another contribution is the notion that rational decision making, the centerpiece of microeconomics of the firm, often plays a relatively small role in strategic decisions about technology. Indeed, organizations change as a result of 'organizational drift' [6] and other factors that have little to do with self-conscious strategic decisions.

One of the more prominent bodies of research and theory in organizational–environment relations is 'environmental contingency theory', which argues that organizational technology, structures and strategy interact, contingent on the demands from the organization's environment, in an effort to reduce organizational uncertainty and to shelter the organization from undesirable environmental changes. Once again, market variables may prove a crucial environmental contingency but a variety of social, technological and political factors may be just as important in determining organizations' technology acquisition and transfer activities.

Another body of work relevant to understanding environmental influences on technology transfer comes from the public organization theory literature. Research on the impacts of political authority on the activities of organizations—both private and public organizations—seeks to explain ways in which firms respond to non-market incentives [7]. Environmentally based theories of organizations have been directly applied to understanding the missions and operations of R&D laboratories. The results indicate that laboratories' technical activities are best understood in terms of the interaction of the political authority exerted on the laboratory and the fit of its knowledge products to market requirements [8,9].

Building on the tradition of organization environment theories, we employ an 'environmental dependence model' to account for differences in R&D laboratories' technology transfer activities. The model assumes that laboratories' strategic choices are constrained by the market, but also by external political authority. However, the laboratories are not without autonomy. Technological strategies are chosen which not only fit environmental demands but also the goal orientation of the laboratory. Furthermore, the laboratory seeks actively to manage and control its dependence...
upon the environment. Figure 1 presents the environmental dependence model.

Fig. 1. Environmental dependence model.

All laboratories, regardless of sector context (industry–government–university), derive the authority to do research and development from some source—market authority, political authority, or some mix of the two. While some organizations in society are chartered under some other type of authority (e.g. religious), almost all R&D laboratories act upon the basis of market and/or political authority and are subject chiefly to market and political constraints [7]. If the laboratory receives its authority and motivation from the market, generally the output from the laboratory will be oriented towards the commercial market. If the laboratory receives its authority and motivation from a political authority base, it is likely that more attention will be given to output that is less directly commercial (e.g. basic research) and that more of its technical product will be directed to other government entities. It is important to note that R&D organizations often operate with a mix of political and market constraints and resources and that sector context is not always a reliable indicator of that mix. One recent study showed that a sizable minority of industrial R&D laboratories are chiefly oriented to public domain science and an equally significant minority of government laboratories are oriented to the production of technical goods aimed directly at the market [8].

The environment creates dependence, chiefly resource dependence, and organizations seek to manage and sometimes exploit the constraints flowing from environmental dependence [10]. The dependence of the laboratories on an authority agent is mitigated by various factors, including deployment of existing resources, boundary spanning, and manipulation of internal structure and control mechanisms.

The goal orientation of the organization—in the present case, the R&D laboratory—can be viewed as a function of its set of environmental constraints, its reservoir of resources and other dependence management assets, leading to a definition of comparative advantage and selection of effectiveness criteria. In turn, any set of scientific and technical activities, including technology transfer, is a function of the goal orientation as determined by environment, dependence, and dependence management. Below, each of the components of the model is described and indicators are developed for the testing of the model.

1.3. Dependence constraints

Consider two factors in terms of authority dependency: funding and vulnerability to environmental change. An adequate budget is a prerequisite for laboratory existence, but the source of funding is a better indicator of environmental dependence. A laboratory whose chief support is from its own industrial organization or parent has a quite different set of environmental constraints and dependence relations than one whose funding comes from government agencies. These differences in constraints and dependence might be assumed to relate, ultimately, to the nature of the organization’s scientific and technical output, particularly technology transfer.

Specifically, we postulate:

Hypothesis One. Laboratories with more funding from government and vulnerability to
shifting political priorities are more likely to engage in technology transfer to other government agencies.

_Hypothesis Two._ Laboratories with greater funding from industrial sources and vulnerability to shifting markets are more likely to engage in technology transfer to industry.

1.4. Dependence management

Organizations deploy resources and develop a variety of mechanisms to manage dependence and to exploit and adapt to their environment. Various factors act to mitigate the dependence of laboratories on either political or market environments.

Probably the most important means of managing dependence is through cultivation of resources and deployment of existing resources. In the case of the R&D laboratory, resources include not only the traditional ones—personnel, budget—but also scientific skills.

_Hypothesis Three._ Laboratories with greater numbers of personnel, especially scientific personnel, and larger budgets are more likely to be involved in transfer of technology to government and industry.

Organization theorists have devoted considerable attention to the role of organization structures in mitigating the environment. Any of a variety of internal structures of organizations can be fashioned (or can evolve) in response to environmental requirements. For example, matrix structure seems to have evolved out of a need to respond to environments that are particularly turbulent, and bureaucratic formalism and ‘over-structuring’ can be interpreted as a response to decrements in internal managerial control. Two structural variables seem especially important for R&D laboratories: the autonomy vs. centralization of R&D tasks and the diversity of the R&D mission. Arguably, research organized around a principal investigator (PI) or PI-led teams might be expected to be more conducive to scientific investigation in basic and, perhaps, applied research. But a more centralized department-based structure might be more attuned with an R&D mission aimed at developing and transferring technology.

Diversity of the laboratory’s scientific and technical activities is a good surrogate for the conventional organization theory concept of organizational complexity. Presumably, an organization with a more diverse set of scientific and technical activities (excluding technology transfer) might also be more oriented to technology transfer because of the synergies involved in the activities and the greater likelihood of appropriating technical knowledge.

_Hypothesis Four._ More complex laboratories with greater diversity of scientific and technical activities are more likely to be involved in technology transfer.

_Hypothesis Five._ Laboratories organized in a more centralized fashion (i.e. by department mode) are more likely to be involved in technology transfer than are laboratories organized in a more decentralized manner (i.e. PI mode).

One of the most important strategies that organizations have available for the monitoring, understanding and shaping of the environment is ‘boundary spanning’. Boundary spanning is the concept used by organization theorists to describe organizations’ efforts to monitor their environments by developing member roles requiring information exchange with external environmental actors. The functions of boundary spanning are to detect information about changes in the external environment and to represent the organization to the environment.

In the context of the R&D laboratory, the director typically plays an important role in boundary spanning and the degree to which the

*Technovation Volume 11 No 4*
director is externally oriented may have substantial implications for the laboratory’s ability to manage dependence and, ultimately, to engage in technology transfer. Technology transfer is, at least to some degree, demand driven and the laboratory director’s boundary spanning activity is often a source of the organization’s definition of external demand. Another source of boundary spanning relates to interorganizational relations. It is argued that interorganizational relations are most often motivated by a jointly perceived need for knowledge about the environment and a need to reduce environmental uncertainty. In terms of the R&D laboratory, one of the most relevant indicators of interorganizational attempts to manage dependence is the existence and number of formal interlaboratory research agreements.

Hypothesis Six. Laboratories engaged in boundary-spanning activity, as reflected in the laboratory director’s external activity and the number of formal interlaboratory research agreements, are more likely to be engaged in technology transfer.

There is some reason to believe that the nature of boundary-spanning activity in a politically dominated environment is distinctive in several respects [13]. Regardless of sector, laboratories in a political environment seek to manage political dependence by cultivating sources of political knowledge and by providing information to political decision makers. Such activities might be expected to relate to laboratories’ propensity to transfer technology to government (without any concomitant effect of technology transfer to industry).

Hypothesis Seven. Laboratories engaged in political boundary spanning, as measured by mail and telephone communication with government and by laboratory directors’ testimony at government agencies’ hearings are more likely to be engaged in technology transfer to government agencies.

1.5. Goal orientation

One of the more fruitful indicators of an organization’s goal orientation or mission definition is its effectiveness criteria. This approach is particularly appropriate in the case of R&D laboratories, which often have goals that are somewhat removed from the parent organization’s goal. Of particular interest is the extent to which the R&D laboratory focuses on goals pertaining to scientific effectiveness and commercial effectiveness. While the two are not necessarily at odds, it is nonetheless the case that many of the laboratories rated highest on one are not rated (by themselves and others) as highly on the other [14]. One might expect that organizations more oriented to commercial goals would be more active in technology transfer.

Hypothesis Eight. Laboratories whose goal orientation, as measured by professed effectiveness criteria, is oriented to commercial factors, are more likely to be involved in technology transfer. Those whose goal orientation is oriented to scientific effectiveness criteria are less likely to be involved in technology transfer.

In light of the hypotheses presented above, the general model of the effects of environmental dependence on scientific and technical enterprise (Fig. 1) can be operationalized for, respectively, technology transfer to industry and technology transfer to government. Figure 2 depicts the effects of a market environment on technology transfer to industry. Dependence constraint is measured in terms of the percentage of the laboratory’s R&D budget derived from the parent industry and other industry sources (RDIND) and response to a questionnaire item about the influence of market forces on selection of research projects (MSELECT). Dependence management variables include total personnel for the laboratory (TOTPER), total budget for the laboratory (TOTBUD) and total scientific
personnel (SCIPER). The boundary-spanning variables for dependence management include a measure of the percentage of time the laboratory director spends on external affairs (DIREXT) and the laboratory's number of formal interlaboratory R&D agreements (LABAGREE). Structure variables pertaining to dependence management include a measure of the diversity of the laboratory's mission (MISDIV) and two measures of the organization of research, a binary variable indicating the presence of division- or department-based organization of R&D (ORGDD) and another for principal investigator-based organization of R&D (ORGPI). Goal orientation is operationalized in terms of responses to two Likert-type scale items, one asking the extent to which scientific criteria are important to the laboratory's definition of effectiveness (EFFSCI), the other asking the extent to which commercial concerns are important to effectiveness (EFFCOMM). Technology transfer to industry is measured in terms of a binary questionnaire item asking whether the activity is a significant part of the laboratory's mission (TRANIND).

The model for technology transfer to government is, in consideration of the distinctiveness of political environments, measured somewhat differently (Fig. 3). The dependence constraint variables are the extent to which government priorities influence the direction of the laboratory's R&D (GSELECT). Other variables include percentage of R&D budget coming from government sources (GOVBUD) and percentage from government grants (RDGRANT). The variables for dependence management are identical to those in Fig. 2 except that a new category is added, political boundary spanning. Variables for this new category include mail received from government sources as a percentage of all the mail received by the laboratory director (GMAIL), a similar measure for phone conversations (GPHONE), and a binary measure based on whether a representative of the laboratory had in the last year served as a witness testifying to a government agency (GTEST). Technology transfer activity is measured as before, except...
in this instance the item refers to transfer to
government agencies (TRANGOV).

2. Study methods and procedures

The data reported in this study were derived
from questionnaires, both mailed and phone
administered. This section begins by describing
the population and approaches to drawing the
sample.

2.1. Population and sample development

Four major research center directories were
used to identify the population of U.S. R&D
laboratories. Laboratories with fewer than 25
reported employees were excluded from the
study population as were those chiefly con-
ducting research in the social sciences. This
yielded a study population of 16,597 R&D
laboratories.

In drawing the sample for this study, both
random probability and stratified sampling
were used. A random probability sample
of 1300 was developed using a computer-
generated random number list. In addition
to a desire to assure representativeness, best
achieved through random probability samp-
ing, it was deemed useful to gather information
about the largest R&D laboratories in the U.S.
Since we were interested in ensuring statistical
significance at the less than 0.01 level for a two-
tailed test, a list of 1300 was drawn for the sam-
ple. The largest 200 laboratories were added to
this list.

2.2. NCRDP questionnaires procedures

The procedures involved developing the
NCRDP questionnaire are described elsewhere
in detail [8]. The design of the questionnaires
was undertaken jointly by the researchers.

An initial master list of questionnaire items
was developed from previous theoretical
frameworks [3, 7], related previous studies, ex-
plicit hypotheses, and articulated concerns of
NSF program managers. In order to determine
possible response bias, question ambiguity and
variance, a pre-test was undertaken.

After considering the results from the pre-
test it was clear that not all of the desired infor-
mation could be obtained from the mailed
questionnaire. The length necessary for the
questionnaire including all the desired items
would have been prohibitive. A telephone
questionnaire was developed. The telephone in-
terviews resulted in the gathering of 665 usable
responses from 1210 telephone contacts for a
response rate of 71%.

A number of steps were taken to minimize
the refusal rate on the over-sampled R&D
laboratory directors. Of the 1341 eligible
laboratories contacted (by phone and ques-
tionnaire) data were received (phone and/or
questionnaire) from 966 for an overall response
rate of 72%. Considering just the mailed
questionnaire, 711 usable responses were re-
cived for a response rate of 53%.

Several steps were taken to determine the
likelihood of non-response bias. Most impor-
tant, the responding laboratories were com-
pared with the entire sample on those variables
about which data were available on the entire
sample, including total personnel and geo-
graphic location. T-test statistics indicated that
the total personnel measures for the group of
respondents were not significantly different (at
the less than 0.25 level) from the entire sample
of laboratories. In regard to geographic loca-
tion, plots were printed for the group of
respondents and non-respondents and no
geographic bias trends were discernible.

3. Findings

Tables 1 and 2 provide cross-tabulations of
the variables sector (government–university–
industry) and technology transfer activity for, respectively, transfer of technology to industry and to government organizations.

The tables indicate that 43.8% of the responding laboratories are engaged in technology transfer to firms and 38.6% seek to transfer technology to government. As indicated by the significance levels of the chi square and Cramer’s $V$ statistics, the sector type seems to have some effects on the incidence of technology transfer to government. However, in the case of technology transfer to industry, the relationship to sector is modest. Each sector is involved in technology transfer to commercial organizations; while government organizations are most active (at least on a percentage basis), at least 40% of the laboratories in each sector view technology transfer to industry as a significant part of their mission.
As a first test of the model presented above, Table 3 presents $T$ tests of the differences in means for each of the independent variables with respect to the group involved in technology transfer to industry and the uninvolved group. From these least restrictive of tests, the environmental dependence model is not rejected. Only one set of structure variables (ORGPI and ORGDD) is not significantly associated with the TRANSIND variable. From the evidence, mode or organizing research projects does not affect propensity to engage in technology transfer to industry. All other variables are in the expected direction.

**TABLE 3. $T$ tests for TRANSIND and independent variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$T$</th>
<th>DF</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSELECT</td>
<td>-6.13</td>
<td>261</td>
<td>0.0001</td>
</tr>
<tr>
<td>RDIND</td>
<td>-2.27</td>
<td>173</td>
<td>0.024</td>
</tr>
<tr>
<td>TOTPER</td>
<td>-2.51</td>
<td>226</td>
<td>0.012</td>
</tr>
<tr>
<td>TOTBUD</td>
<td>-2.57</td>
<td>259</td>
<td>0.010</td>
</tr>
<tr>
<td>SCIPER</td>
<td>-2.32</td>
<td>173</td>
<td>0.005</td>
</tr>
<tr>
<td>DIREXT</td>
<td>-3.77</td>
<td>172</td>
<td>0.0002</td>
</tr>
<tr>
<td>LABAGREE</td>
<td>-1.69</td>
<td>158</td>
<td>0.091</td>
</tr>
<tr>
<td>MISDIV</td>
<td>-10.94</td>
<td>256</td>
<td>0.0001</td>
</tr>
<tr>
<td>ORGDD</td>
<td>-1.48</td>
<td>176</td>
<td>ns*</td>
</tr>
<tr>
<td>ORGPI</td>
<td>0.22</td>
<td>176</td>
<td>ns*</td>
</tr>
<tr>
<td>EFFSCI</td>
<td>2.93</td>
<td>175</td>
<td>0.003</td>
</tr>
<tr>
<td>EFFCOMM</td>
<td>-4.83</td>
<td>175</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*ns = not significant.

Table 4 gives similar information for the relationship of the predictor variables to TRANSGOV. Once again, the two structure variables do not appear to be strongly related to technology transfer activity, but other variables are significant and in the expected direction.

A somewhat more stringent test is provided in Table 5, which gives Kendall’s tau correlations between the predictor variables of the two models and the respective technology transfer variables. The model for technology transfer to government appears to perform better. When considering significance levels it should be remembered that the exclusion of industry laboratories from the TRANSIND model cuts the sample size substantially. But the magnitudes of the correlation also indicate better performance with respect to TRANSGOV.

**TABLE 4. $T$ tests for TRANSGOV and independent variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$T$</th>
<th>DF</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSELECT</td>
<td>-5.98</td>
<td>641</td>
<td>0.0001</td>
</tr>
<tr>
<td>RDGRANT</td>
<td>-3.41</td>
<td>395</td>
<td>0.0007</td>
</tr>
<tr>
<td>GOVBUD</td>
<td>-12.41</td>
<td>407</td>
<td>0.0001</td>
</tr>
<tr>
<td>TOTPER</td>
<td>-3.73</td>
<td>585</td>
<td>0.0002</td>
</tr>
<tr>
<td>TOTBUD</td>
<td>-5.12</td>
<td>580</td>
<td>0.0001</td>
</tr>
<tr>
<td>SCIPER</td>
<td>-2.77</td>
<td>390</td>
<td>0.005</td>
</tr>
<tr>
<td>LABAGREE</td>
<td>-1.78</td>
<td>373</td>
<td>0.075</td>
</tr>
<tr>
<td>MISDIV</td>
<td>-11.55</td>
<td>618</td>
<td>0.0001</td>
</tr>
<tr>
<td>ORGDD</td>
<td>-0.70</td>
<td>410</td>
<td>ns*</td>
</tr>
<tr>
<td>ORGPI</td>
<td>-1.68</td>
<td>410</td>
<td>0.091</td>
</tr>
<tr>
<td>GPHONE</td>
<td>-12.04</td>
<td>407</td>
<td>0.0001</td>
</tr>
<tr>
<td>GMAIL</td>
<td>-11.50</td>
<td>406</td>
<td>0.0001</td>
</tr>
<tr>
<td>GTTEST</td>
<td>-2.66</td>
<td>408</td>
<td>0.008</td>
</tr>
<tr>
<td>EFFSCI</td>
<td>-3.51</td>
<td>407</td>
<td>0.0005</td>
</tr>
<tr>
<td>EFFCOMM</td>
<td>-5.50</td>
<td>407</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*ns = not significant.

**TABLE 5. Kendall’s tau correlations of independent variables and technology transfer variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>$T$</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSELECT</td>
<td>0.351***</td>
<td>na</td>
</tr>
<tr>
<td>GSELECT</td>
<td>na</td>
<td>0.230***</td>
</tr>
<tr>
<td>RDIND</td>
<td>0.121</td>
<td>na</td>
</tr>
<tr>
<td>RDGRANT</td>
<td>na</td>
<td>0.187***</td>
</tr>
<tr>
<td>GOVBUD</td>
<td>na</td>
<td>0.470***</td>
</tr>
<tr>
<td>TOTPER</td>
<td>0.148**</td>
<td>0.050</td>
</tr>
<tr>
<td>TOTBUD</td>
<td>0.152**</td>
<td>0.287***</td>
</tr>
<tr>
<td>SCIPER</td>
<td>0.137*</td>
<td>0.027</td>
</tr>
<tr>
<td>DIREXT</td>
<td>0.214***</td>
<td>0.171***</td>
</tr>
<tr>
<td>LABAGREE</td>
<td>0.115</td>
<td>0.121*</td>
</tr>
<tr>
<td>MISDIV</td>
<td>0.501***</td>
<td>0.370***</td>
</tr>
<tr>
<td>ORGDD</td>
<td>0.111</td>
<td>0.034</td>
</tr>
<tr>
<td>ORGPI</td>
<td>0.016</td>
<td>0.082</td>
</tr>
<tr>
<td>GPHONE</td>
<td>na</td>
<td>0.483***</td>
</tr>
<tr>
<td>GMAIL</td>
<td>na</td>
<td>0.450***</td>
</tr>
<tr>
<td>GTTEST</td>
<td>na</td>
<td>0.131**</td>
</tr>
<tr>
<td>EFFSCI</td>
<td>-0.238***</td>
<td>0.165***</td>
</tr>
<tr>
<td>EFFCOMM</td>
<td>0.312***</td>
<td>0.246***</td>
</tr>
</tbody>
</table>

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. na = not in model.
The table indicates that laboratories engaged in technology transfer to industry tend to be vulnerable to changes in the market, have a large number of total personnel working in the laboratory, have a large number of scientific personnel, have an externally oriented laboratory director, and, most important (at least statistically), a more diverse R&D mission. As expected, emphasis on scientific effectiveness criteria is negatively associated with technology transfer to industry, commercial effectiveness criteria are positively related. The picture for technology transfer to government is somewhat different. Each of the political boundary-spanning variables is significant and strongly related as is the percentage of total budget from government sources. Personnel composition—total numbers and scientific personnel—does not account for technology transfer to government.

Strictly speaking, an ordinary least-squares regression model may not provide an appropriate interpretation for the binary dependent variables, and an alternative approach is therefore employed below. However, it is of some value to employ this generally robust technique as a test, albeit a problematic one, of the environmental dependence model. A “trimmed” three-variable model is employed in connection to explain, respectively, TRANSIND and TRANSGOV. In each model, the best predictor variables are drawn from each of the conceptual categories (e.g. dependence constraints, dependence management, goal orientation). The trimmed regression model for TRANSIND includes MSELECT (Dependence Constraint), MISDIV (Dependence Management), and EFFCOMM (Goal Orientation). The trimmed regression model for TRANSGOV includes GOVBUD (Dependence Constraint), MISDIV (Dependence Management), and EFFCOMM (Goal Orientation). Table 6 gives the results for each of the models.

The results reveal that the three-variable models work quite well, with an R-square of 0.408 for the TRANSIND model and 0.401 for the TRANSGOV model. Each of the predictor variables makes a substantial contribution in accounting for unique variance. Each of the signs is in the hypothesized direction. The question remains, however, whether the results might be an artifact of violation of test assumptions with the dichotomous dependent variables.

An appropriate regression-based model for dichotomous dependent variables is provided with the logit procedure. Table 7 reports the results of the logit application for each of the trimmed models. The results are supportive of the models in much the same manner as the OLS analysis. By convention, the gamma statistic is employed to evaluate the power of the logit model (as it is not appropriate to view the logit procedure as explaining variance) and, in both instances, the magnitudes of the gammas indicate a strong model. One point of interest is the vanishing of the EFFCOMM variable in the TRANSGOV model, perhaps because of the distribution of its variances with respect to the dichotomous dependent variable. The chief point, however, is that with a conceptually elegant three-variable model, the technology transfer activity of R&D laboratories is well explained, lending support for further development of the environmental dependence interpretation of scientific and technical enterprise.
4. Summary and Conclusions

This paper has sought to explain the technology transfer activity of R&D laboratories by developing and testing an environmental dependence model of scientific and technical enterprise. The model assumes that scientific and technical activity is a function of environmental constraints flowing from the organization's market and political influences. As the organization seeks to manage constraints and develop a goal or mission orientation, it chooses to focus on technical activity that is adaptive for its environment. An assumption of the model is that the R&D laboratory's mix of political and market constraints is a more significant factor in accounting for its scientific and technical choices than is its sector (university, industry, government) affiliation.

Simple tests of the model (T tests and Kendall's tau correlations) indicated that each of the terms of the model offer some predictive value. The lone exception is the structure for organizing research projects. Scientific and technical mission diversity is particularly important in understanding technology transfer to both government and industry. However, a variety of measures of political boundary spanning are quite important in transfer to government but not so to industry. Likewise, the nature of the resource base (government vs. industrial) is strongly related to the choice of transfer technology to, respectively, government and industry.

Both an OLS estimation and a logit-based model were developed to provide a test of a trimmed three-variable model employing only one measure for each major construct of the environmental dependence model. The regression model was effective in accounting for variance in technology transfer behavior and the technically more appropriate logit model, likewise, provided support for the environmental dependence interpretation.

A variety of next steps seem promising. It will be useful to go beyond technology transfer to the explanation of the entire range and mix of scientific and technical activities. There are also some measurement challenges. The actual dynamics of the environmental dependence model are not tested here. A path analysis, testing direction of influence, seems a needed step once stronger measures of scientific and technical activity are developed.

The findings seem suggestive with respect to public policy for technology transfer. One somewhat surprising finding was that cooperative R&D, as measured by number of interlaboratory agreements, was not a strong predictor of technology transfer to either firms or to government. In light of the recent policy emphasis given to cooperative R&D this finding, while preliminary, at least sounds a note of caution. Granted, there is no measure employed here other than the number of agreements and it is possible that the structure and quality of the agreements is much more important than the raw number. Nevertheless, if laboratories engaging in cooperative R&D are only a bit more likely than others to engage in technology transfer then the short-term value of cooperative R&D is open to question.

One of the most important factors in determining technology transfer activity is the diversity of the laboratories' missions. When we
take this finding along with the finding that laboratories with larger total budgets and larger numbers of scientific personnel are more likely to be engaged in technology transfer. We might surmise that there are significant threshold effects operating in technology transfer and that only those laboratories with a given level of capacity are likely to be active technology transfer partners. In an era of limited resources, recognizing specialized roles and tailoring policy requirements to laboratory strengths seems to make sense. Not every laboratory is well suited to be a technology transfer partner and, moreover, technology transfer activities may even get in the way of more important activities such as basic research, technology development or education.

Perhaps one of the most significant implications of the paper is simply the identification of the number of laboratories engaged in technology transfer activities. With more than half of all government laboratories engaged in technology transfer and fully 40% of the no-longer-ivory-tower university laboratories active as technology transfer partners, we can assume that the various environmental influences, whether market opportunity or political mandates, have had the effect of enticing large numbers of laboratories to fly the technology transfer banner. Now it is important to begin to understand the impact of this level of activity and the ways in which it has transformed individual laboratories and the U.S. R&D laboratory system.

Notes

1 This is a revision of a paper presented at the First Annual Korea-U.S. Seminar on Science and Technology Policy, Center for Science and Technology Policy, Korea Institute of Science and Technology, Seoul, Korea, November 3-6, 1989. The paper is part of the National Comparative Research and Development Project. The authors gratefully acknowledge funding of the National Science Foundation, Science Resources Section.

2 Some of the recent federal-level legislation pertaining to technology transfer should be briefly noted. The Stevenson-Wydler Technological Innovation Act of 1980 required government laboratories to set aside 0.5% of their budget to be directed to technology transfer and mandated the formation in each laboratory with more than $20 million budget of an Office of Technology Applications and, finally, facilitated personnel exchanges between government laboratories and universities and industry. The Bayh-Dole Act of 1980 permitted small businesses and not-for-profit organizations to retain title to inventions even if produced with federal funds. The National Cooperative Research Act of 1984 codified rulings by the Department of Justice aimed at easing antitrust laws applied to joint ventures among firms and between firms and federal laboratories. The Federal Technology Transfer Act of 1986 extended Stevenson-Wydler, formalized the Federal Laboratory Consortium, and authorized federal laboratories to increase to 15% the royalties employees receive for inventions successfully commercialized. Executive Order #12591, signed in 1987, required federal laboratory directors to be responsible for entering into cooperative research agreements.

3 This is the definition employed when we gathered questionnaire data about organizations' technology transfer activities.

4 For a review of the contingency theory literature see ref. 17.

5 For evidence that performance is a function of the laboratory's ability to align its set of environmental constraints with its dominant output orientation see ref. 9.

6 For a theory of organizations' strategies for managing dependence and environmental constraints see refs 10 and 18.

7 This is an additive variable based on responses to dichotomous choices for the following activities: basic research, applied research, development of prototype devices, technical assistance, and technological demonstration.

8 The researchers recognized that the data provided in the most recent standard research directories would necessarily be somewhat out of date and would entail at least a few coding and other errors. To compensate for these problems, each of the 1500 laboratories was telephoned by the researchers and their staff in order to confirm the continued existence of the laboratory, correct addresses, to develop data about areas of research focus and total personnel, and to confirm the name of the current laboratory director. As a result of this process, the study sample was reduced from 1500 to 1341.
A separate sample random probability sample of 60 was drawn from the population by identical computer-generated random number techniques. In addition, to indicate the response patterns for the 200 largest R&D laboratories (the "superlabs"); a group of the next 20 largest (201-221) was included in the pre-test. After a period of 1 month had elapsed from the time of the follow-up letter (7 weeks from the initial mailing of the pre-test questionnaire), the pre-test was closed. From the 80 questionnaires mailed, 31 usable questionnaires were returned. The researchers analyzed the responses in order to determine possible ambiguities, degree of response variation, and, comparing known characteristics of the respondents with known characteristics of the population, degrees of non-response bias. From this information, the questionnaire was revised again.

Some R&D directors indicated that they averaged as many as five or six mailed questionnaires per month. In order to distinguish this study and to minimize the response rate the following steps were taken: (1) personalized alert and cover letter; (2) confirming phone call; (3) first class postage; (4) high quality paper; (5) multicolor but subdued colors; (6) science indicators incentive; (7) high quality printing; (8) pleasing format without crowding; (9) easy implementation with few open-ended questions; (10) return postage provided; (11) "hotline" telephone number for questions.

Another measure of non-response bias is "wave analysis". That is, determining whether those who respond more quickly are significantly different from those who respond later. The theory is that the later respondents, if different, will tend to be more like those that did not respond at all. Correlation with date of response indicated that only size variables were significantly correlated (larger laboratories responding later) but the correlations were modest and, moreover, the stratification by size provided some hedge against possible non-response bias. It was concluded that no substantial problems of non-response bias were apparent as one would expect with such a relatively large response rate.

In each stage of analysis there is a distinction between the database for the examination of, respectively, TRANIND and TRANGOV. In the case of TRANIND, only university and government R&D laboratories are considered because of the lack of perceived construct validity of the question asking industry labs to indicate if they transfer technology to industry. An affirmative response might mean that technology is transferred to a parent, out of the laboratory to the organization, or to another industrial organization. It was not possible, moreover, to ask a question sufficiently detailed to capture this nuance. In the case of technology transfer to government (TRANGOV) the industry laboratories are included because there is no similar ambiguity in response.

It is absolute number of scientific personnel that is important, perhaps as a size surrogate; ratio of scientific personnel to total personnel was not significantly related.

Given the limitations of regression for dichotomous data, no attempt is made to develop path coefficients for the models.

References

Technology transfer from U.S. R&D laboratories


Barry Bozeman is Director of the Technology and Information Policy Program and Professor of Public Administration and Affiliate Professor of Engineering, The Maxwell School of Public Affairs, Syracuse University. His research has focused on technology transfer, innovation, and R&D laboratory policy. Bozeman received his Ph.D. in political science from Ohio State University in 1973.

Michael Crow is Director of the Institute for Physical Research and Technology, Iowa State University. His research interests include science and technology policy, technology and economic development, and universities’ strategies for acquiring funds for science infrastructures. Crow has authored or co-authored several books including Strategic Management of Industrial R&D and Synthetic Fuel Technology Development in the United States. Crow received his Ph.D. in public administration from the Maxwell School, Syracuse University, in 1985.

Le transfert de technologie provenant du gouvernement et des laboratoires de recherche-développement aux EEUU

RÉSUMÉ

Malgré l’accroissement d’interêt au transfert interne de technologie, il y a étrangement très peu de preuves empiriques sur les déterminants d’activité de transfert de technologie. Cet étude présente les résultats d’un sondage national sur plus de 900 laboratoires, se concentrant sur un sous-échantillon comprenant 134 laboratoires gouvernementaux et 139 laboratoires universitaires. Un modèle d’activité de transfert de technologie de dépendance du milieu est présenté, et on propose que l’influence de l’autorité politique constitue l’un des éléments les plus importants qui déterminent l’activité de transfert de technologie. Plusieurs tests du modèle indiquent que la diversité scientifique et technique des missions est particulièrement importante pour comprendre le transfert de technologie vers le gouvernement autant que vers l’industrie. Néanmoins un certain nombre de mesures de couverture des limites au niveau politique sont assez importantes dans le cas de transfert vers le gouvernement mais non pas vers l’industrie. Egalement la nature de la base des ressources (gouvernement contre industrie) est fortement relié au choix de transférer la technologie vers le gouvernement et vers l’industrie respectivement.

Technologietransfer von U.S. Regierungs- und Universitäts R&D Labors

ABRISSE

Trotz zunehmendem Interesse an inländischem Technologietransfer, gibt es überraschend wenig empirisch erstellte Daten über die entscheidenden Faktoren, die Technologie aktivieren. Diese Untersuchung bringt, die Ergebnisse einer Umfrage bei 900 Labors im Lande, insbesondere einem Subsample von 134 Regierungs labors und 139 Universitätslabors.
Ein umweltabhängiges Model von Technologietransferaktivität wird erstellt, das als wichtigsten entscheidenden Faktor von Technologietransferaktivität den Einfluß politischer Autorität vorbringt. Beim Erproben des Models ergab sich daß wissenschaftliche und technische Verschiedenartigkeit der Aufgaben besonders wichtig sind, wenn man Technologietransfer zur Regierung und zur Industrie verstehen will. Doch sind eine Reihe von Maßnahmen bezüglich politischer Einschränkungen im Transfer zur Regierung wichtig, nicht aber zur Industrie. Desgleichen bestimmt die Beschaffenheit der Aktiva (Regierung/Industrie) hauptsächlich die Wahl des Technologietransfer an Regierung und Industrie und deren Anwendung.

La Transferencia de la Tecnología entre el gobierno de los EE.UU. y los laboratorios de investigación y desarrollo de las universidades

RESUMEN

Aunque el interés en la transferencia de tecnología doméstica aumenta cada vez más, la falta de pruebas empíricas de los factores determinantes de la actividad de la transferencia de la tecnología sorprende. En este estudio se presentan los resultados de un sondeo nacional de más de 900 laboratorios, con énfasis especial en un sub-grupo de 134 laboratorios gubernamentales y 139 laboratorios universitarios. Se ofrece un modelo de actividad de transferencia de tecnología con dependencia ambiental. Se propone en el argumento que la influencia de autoridad política tiene un efecto determinante importante en la actividad de la transferencia de tecnología. Algunas pruebas llevadas a cabo del modelo indican que las distintas misiones científicas y técnicas tienen una importancia particular tanto para el gobierno como para la industria a la hora de entender la transferencia de tecnología. Sin embargo, varias medidas de definición de campo político tienen bastante importancia para el gobierno mientras no lo tengan para la industria. De la misma forma, existe una fuerte relación entre el tipo de base de recurso (o bien el gobierno o bien la industria) y la decisión de transferir la tecnología, respectivamente, al gobierno o a la industria.