Universities as Research Partners

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Revised September 2001

Abstract

Universities are a key institution in the U.S. innovation system, and an important aspect of their involvement is the role they play in public/private partnerships. This note offers insights into the performance of industry/university research partnerships using a survey of pre-commercial research projects funded by the Advanced Technology Program. Although results must be interpreted cautiously because of the small size of the sample, the study finds that projects with university involvement tend to be in areas involving "new" science and therefore experience more difficulty and delay yet are more likely not to be aborted prematurely. Our interpretation is that universities are contributing to basic research awareness and insight among the partners in ATP-funded projects.

JEL Code: O32
Keywords: R&D policy; technology policy; university-industry partnership; basic research

We are grateful for comments on earlier versions from William L. Baldwin, Adam Jaffe, Don Siegel, participants at the ASSA 2000 meetings in Boston and the Wake Forest University economics workshop, and an anonymous referee. Also, we appreciate the suggestions and guidance of Rosalie Ruegg and Jeanne Powell, both of the Advanced Technology Program, during the data collection stage.

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I. Introduction

Many observers have emphasized the importance of research partnerships for U.S. innovative capacity (Council on Competitiveness 1996, pp. 3-4). Indeed, industry/university research relationships appear to have strengthened over the past few decades. University participation in formal research joint ventures (RJVs) has increased steadily since the mid-1980s (Link 1996), and the number of industry/university R&D centers has increased by more than 60 percent during the 1980s. Cohen et al. (1997) and a recent survey of U.S. science faculty revealed that many universities desire even more partnerships with industry (Morgan 1998). Yet surprisingly, very little is known about the types of roles that universities play in such research partnerships or about the economic consequences associated with those roles. Our investigation is a first effort—an exploratory inquiry—to provide empirical information about universities as research partners.

Previous research falls broadly into either examinations of industry motivations or of university motivations for engaging in an industry/university research relationship. That research has not investigated the economic impacts associated with university participation as thoroughly as the motivations. Hall, Link, and Scott (2000) review the literature and document its identification of two broad industry motivations for industry/university RJVs. The first is access to complementary research activity and research results; the second is access to key university personnel. The literature shows university motivations to be largely financially based. This note reports on the results of a small survey of such partnerships that focuses on their performance rather than the reasons underlying their formation.

II. An Analysis of the Data

A. Identifying an Appropriate Database

Given the potentially heterogeneous research role for universities, we developed and analyzed project-level data from the Advanced Technology Program (ATP), established within the National Institute of Standards and Technology (NIST) through the Omnibus Trade and Competitiveness Act of 1988. The ATP combines public funds with private investments to create and apply generic technology needed to commercialize new technology rapidly; it received its first appropriation from Congress in FY 1990.

ATP projects will not give a complete picture of industry/university R&D interaction. These projects are likely to have high social value and high risk, involve largely generic rather than largely proprietary technology, and be at such an early stage in development that the technology is not easily appropriable. Nonetheless, describing universities' roles in RJVs spawned by the ATP provides long-overdue insights about universities as research partners with industry.

Hall, Link, and Scott (2000) describe the population of ATP projects in terms of the numbers of awards since the program began, status of the projects (active, completed, or terminated) and organizational types (single participants or RJVs), funding characteristics (mean total funding and the proportions from public and private sources), project durations, technology areas, and university involvement by technology area. We refer herein to some of the population characteristics, but the complete overview provides important additional detail.

In addition to classifying each project into a unique technology area, ATP classifies each project by lead participant. Each lead participant is placed into one of four ATP-defined type/size categories including not-for-profit organizations.[1] Among the for-profit organizations, small is defined as an organization with fewer than 500 employees; large is defined as a *Fortune* 500 or equivalent organization (a moving definition, $2.6 billion in revenue at the time of our analysis). All others are medium. More than one-half of the lead participants are small.

B. Selecting a Sample of ATP-Funded Projects

We selected our sample of projects from the population of 352 projects funded by ATP from April 1991, when its first awards were made, through the start of our study in October 1997, using a series of filters, some under our control and others not. The first filter was that 21 projects terminated early (analyzed below) and were therefore unavailable for sampling. The second filter was that each project must be active and have been active for at least one year to help ensure the respondent's use of a research project history when responding to the survey. These two filters reduced the population of 352 projects to 192 projects. The 192 projects were then grouped by the six types of university involvement, listed in Table 1 (column 3).[2] From each of the categories, a sample of 9 projects was selected (column 4), with attention given to technology areas, sizes of lead participants, lengths of time the projects had been active, and total proposed research budgets of the projects. Also reported in Table 1 are the sampling probabilities by type of university involvement.[3] This process of random stratified sampling yielded 54 projects.

Separate and distinct survey instruments were designed to obtain information about the nine projects selected in each of the six categories of university involvement.[4] Table 1 (column 6) shows the number of surveys received.[5] With 7 non-respondents, our sample for analysis is 47.[6]

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[1] Non-profit lead partners are not classified with respect to size, nor do we have revenue for these partners. This fact has two implications: 1) all of the size effects we measure are for for-profit lead partners, and 2) it is essential to include the non-profit dummy when we include size in the regression in order to avoid misleading conclusions.

[2] In an industry/university-relationship, the university is either a subcontractor; or it is a research partner, which means that the university is a formal member of the joint venture.

[3] Variability in these probabilities reflects that the sample size is constant at nine and that the size of the population of appropriate projects to sample, by category type, varies (column 3).

[4] Copies of the survey instruments are available upon request from the authors.

By ATP guidelines, universities cannot be lead partners. RJVs where the lead partner is a not-for-profit organization do have an affinity for inviting universities to be research partners. Yet the sample distinguishes such cases from RJVs with a university partner yet no not-for-profit lead partner. Thus, the effects of non-profit lead partners and the effects of universities on RJV performance can be distinguished in our sample: there are 10 RJVs with a university and a non-profit lead partner, 8 with a university but no non-profit lead partner, 1 with a non-profit lead partner but no university, 17 with no university and no non-profit partner, 9 non-RJV projects with a university subcontractor, and 9 non-RJV projects with no university subcontractor. In sum, our sample has no non-profits (as the main participant apart from any subcontractor) in the non-RJV observations, and non-university non-profits are mainly involved in RJVs with universities. However, the two—universities and non-profit lead partners—are not the same thing (note the number of RJVs with universities without a nonprofit lead partner), and sometimes in our exploratory analyses of performance, coefficients for both universities and for non-profit lead partners are identified.

C. Analysis of Terminated Projects in the Population

We investigated the reasons for the early termination of 21 projects among the population of 352. These reasons ranged from the financial health of the participant(s) to lack of research success in the early part of the project. We estimated a probit model of termination probability conditional on ATP's share of funding, involvement of a university, type of project, size of the lead participant, and technology area.[7] A time variable denoting the year in which each project was initially funded was also included.

The probit estimates from alternative specifications are reported in Table 2. Our particular interest is the nature of the relationship between university involvement and termination. The results imply that the projects with university involvement as either a research partner or subcontractor have a lower probability of early termination. Also, the probability of early termination decreases as ATP's share of funding increases, although the effect is barely significant, and only for the specification used to simulate the

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[5] Because there are multiple dimensions of ATP-funded projects, we do not claim that our sample of 47 respondents is representative of the filtered population or of the whole population in all dimensions. We offer our sample as one sample to consider, and possibly to generalize about, given the stated filtering and selection process. More detailed information about the representativeness of the sample by other characteristics of ATP-funded projects is available from the authors.

[6] We are aware of the limitations of the self-reported data that will be analyzed below. While our survey instruments were pre-tested, the possibility that our primary data reflect the personal attitudes of the respondents as well as objective characterizations of their projects is still present. Thus, while this study is one of the first of its kind in attempting to quantify the role of universities in research partnerships, efforts to generalize from our findings should be made with the utmost caution.

[7] To be precise, we estimated the following model: *Pr(project i terminates early)* = $F(\boldsymbol{X}_i \boldsymbol{\beta})$ where F is the cumulative normal probability function and $\boldsymbol{X}_i$ is a vector of variables that characterizes project *i*.

predicted probabilities shown in Table 3. The termination rate does not vary across technology area,[8] but projects where the lead partner is of medium size are more likely to terminate early than the others.

The upper portion of Table 3 presents the calculated probabilities for a project terminating early, by size of lead participant. For this example (information technology projects begun in 1991), the calculated probability of early termination is lower for each size category when a university is involved in the project. Similarly (lower portion of Table 3), the calculated probability of early termination is lower for each discrete level of ATP's share of funding when a university is involved in the project.[9] In the population of ATP projects, university involvement is clearly associated with a lower probability of early termination.[10]

D. Estimating the Probability of Response to the Sample Survey

Only two of the six categories of university involvement listed in Table 1 (column 6) had a 100 percent response rate. Contacts in joint ventures were less likely to respond, with the least responsive category being joint ventures with universities as both partners and subcontractors—only five of nine surveys were returned. We examined the probability of survey response using a probit model. When we include all of the right hand side variables, nothing is very significant. The only variable that is even marginally informative is the dummy for joint ventures with universities as both partner and subcontractor (JVUS), arguably the most complex arrangement contractually. Other factors held constant, joint ventures with universities as research partners and as subcontractors have a lower probability of response.

In the results presented below, we test and correct for response bias simply by including the JVUS dummy in our estimations.[11] The implication of this strategy will be that we cannot identify the direct

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[8] This conclusion needs to be qualified slightly: because no projects in other manufacturing terminated early, these projects could not be included in the models estimated in the first 2 columns of Table 2 (where we use technology dummies). Clearly projects in this technology area have a lower early termination rate than projects in the other technology areas.

[9] Similar relationships, available from the authors, exist across other research technology areas.

[10] The information in Table 2 is used to calculate a hazard rate for the probability that a project does not terminate early for use in the subsequent statistical analyses of a sample of ATP-funded projects to control for possible sample selection bias. To anticipate the use of this variable in later survey question equations, it is important to note that its inclusion in an ordered probit is not really econometrically correct if it actually enters. That is, if the probability distribution in the termination equation and the distribution in the survey question equation are dependent, then the appropriate method is to specify a full maximum likelihood model for the two random variables and estimate jointly (such a model is outlined in Hall, Link, and Scott 2000). In fact, we found that the termination hazard and the sample response hazard never entered significantly, and that joint maximum likelihood estimates did not differ significantly from our single equation estimates, which implies that sample selection is unlikely to produce significant bias in our estimates. However, our sample size is small, so the power of all these tests is low.

[11] As with our analysis of the probability of early termination, the results from the response probit model could be used to calculate a survey hazard rate for the statistical analyses that follow. However, in practice, the only variable that predicted response or non-response in a simple probit model was JVUS. We therefore used a simpler and more robust method to correct for response bias, by including the JVUS dummy directly in our estimated model. Unlike the use of a hazard rate, this correction does not require normality of the response probability equation to be valid. For a single dummy variable predictor, of course, the two approaches for converting any response bias would be equivalent if normality held.

effects of being a joint venture with a university participating as a partner and as a subcontractor separately from the impact on the probability of survey response.

III. Role of Universities in ATP-Funded Projects

We ask three general questions about the roles of universities as research partners:

1. What roles do universities play in research partnerships in general?
2. Do universities enhance the research efficiency of research partnerships?
3. Do universities affect the development and commercialization of industry technology?

A. Role Played by Universities in ATP-Funded Projects

What research role do universities play in ATP-funded projects? At one level, the answer to this question comes from the organizational or administrative role that universities have in various projects. In a joint venture, the research role of a university is either as a research partner in the joint venture or as a subcontractor to the joint venture. In single applicant projects, the research role of a university is only as a subcontractor by definition of the project being a single applicant project.[12]

At a second level, we explored the role played by universities by asking each contact person to indicate, using a 7-point Likert scale, the extent to which the research project experienced difficulties acquiring and assimilating basic knowledge necessary for the project's progress. Strong agreement that such difficulties had been experienced was indicated with a 7, with the responses ranging downward to 1 to indicate strong disagreement. Ordered probit models were estimated to explain inter-project differences in responses about the difficulties. Held constant in these models are several characteristics of the project as determined from ATP information and from survey responses.

The estimates are in Table 4. In column 1 we include the hazard rate for non-termination (the conditional probability density that the project will go forward to completion) and the proxy for the survey response hazard (JVUS) in the model. Neither of these enters into the equation significantly, implying that selection bias is unlikely to be a problem for our estimates.[13]

We have five observations about the estimates in Table 4:

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[12] Related to this organizational or administrative research role that universities have is another level at which to answer the first research question. Four of the six groups of contact persons for the survey were asked why the university subcontractors on this project were selected. For joint ventures where a university is only involved as a subcontractor and for single participants where the university is only involved as a subcontractor, the most frequent response was that the subcontractor was selected to gain access to eminent researchers. Joint ventures in which the university is only involved as a research partner reported that the university was invited to participate most commonly because of previous research interactions with other members of the joint venture. And, finally, the dominant response when universities are involved in a joint venture as research partners and as subcontractors (JVUS) was that each was selected based on their overall research reputation.

[13] For completeness, we have estimated the full model for sample selection (an ordered probit equation plus an equation for the probability that the survey was returned), and the selection into the sample does not appear to be important for our results (Hall, Link, and Scott 2000).

1. Respondents with a university participant (as a research partner or as a subcontractor) systematically agreed that the project has experienced difficulties acquiring and assimilating basic knowledge necessary for progress toward completion. Joint venture projects are larger than others, which tends to lower difficulty in general but raise it if a partner is a university. That is probably also consistent with such projects being more "difficult" or closer to "new" science than are others; and hence, the university partner was chosen in anticipation of the difficulties. Or, the university's presence may create a greater awareness that such difficulties exist.

2. Prior experience working with a university as a research partner or as a subcontractor is a significant factor in decreasing the difficulty of acquiring and assimilating basic knowledge.

3. Acquisition and assimilation difficulties with basic knowledge decrease slightly as overall project size increases.

4. Projects in the electronics area have substantially more difficulty in acquiring and assimilating basic knowledge than do projects in other technology areas.

5. Projects with larger for-profit lead partners or non-profit lead partners have experienced difficulties acquiring and assimilating basic knowledge.

B. Research Efficiencies from Universities in ATP-Funded Projects

Are there systematic differences in the research efficiency of ATP-funded projects that have universities involved and those that do not? We addressed this question of research efficiency by asking each contact person to respond to a series of five statements. The first three of these statements investigate unexpected research problems encountered relative to expectations when the project began. Had the number of problems encountered been more than, less than, or about the same as what had been anticipated at the project's outset? The three types of research problems investigated are conceptual research problems, equipment-related research problems and personnel research problems.

To evaluate the responses to the first three statements, ordered probit models were estimated. Held constant in these models are several characteristics of the project as determined from ATP information and from survey responses.[14] In the specifications for conceptual problems and for equipment problems, none of the individual variables was significant in explaining the existence of unexpected conceptual or equipment-related research problems, apart from the perhaps obvious fact that problems with research about information technology were not equipment-related. Because only a few projects had fewer problems of any type than expected, we experimented with collapsing the responses from the original three categories (the number of problems encountered were more than, less than, or about the same as

[14] Ordered probit models that allowed for sample selection were also estimated, but proved to be very difficult to identify because of the small sample. Therefore we rely mainly on the ad hoc correction terms discussed above; hence the effect for university participation cannot be disentangled from the selection effect.

what had been anticipated at the project's outset) into two categories. Even when re-estimated in this form in probit models, essentially no identifiable individual variable effects explained the existence of unexpected research problems. The presence of unexpected problems is perhaps random or a complex result of many factors that we cannot disentangle—truly "unexpected" given the information available to the firm (and to us).

Table 5 shows the specification for personnel problems, and the estimates suggest that the presence of "unexpected" personnel-related problems is associated somewhat with the technology field. Lead partner size is a marginally significant explanatory variable in explaining the presence of unexpected personnel problems; projects with non-profit lead partners are less likely to experience this kind of problem although the effect is not significant. Joint ventures with university partners are both more likely to have personnel-related problems and, as we saw above, also less likely to respond to the survey, so we cannot disentangle these two effects.

The fourth and fifth statements addressed aspects of research efficiency related to the productive use of complementary research resources. The first of these asks for the approximate percentage of the project's research time that, in retrospect, had been unproductive. The second asks for the approximate percentage of the project's financial resources that, in retrospect, had been unproductive. These two statements are analyzed together because of the high correlation between responses. Twenty-two of 42 contact persons responded to both questions with the same percentage.

Table 6 uses an ordered probit model to evaluate the responses across the categories of approximate percentage response.[15] Although we originally included all variables in the estimation, only the size of the lead partner and the technology variables were significant, and Table 6 presents the model with just those effects and the effects of a university participant or a non-profit lead participant. Unproductive time and cost is associated most with electronics projects and associated least with information technology and manufacturing projects. Projects with university participants are more likely to report unproductive costs.

Comparing further the estimates in the two columns of Table 6, projects in electronics have the largest share of time and money that is unproductively used whereas projects in manufacturing have the least. Unproductive research time and money in electronics may be related to projects in this field also having difficulty acquiring and assimilating the basic research they need. Biotechnology projects have relatively little unproductive research expenditure, although somewhat more unproductive research time. Larger (profit-making) lead partners are better at making productive use of research time and expenditure, or at least they perceive that to be the case.

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[15] Note that this survey statement addresses realized unproductive research time and not expected unproductive research time. The same is true for the unproductive use of financial resources.

C. Accelerated Development and Commercialization of Technology from Universities in ATP-Funded Projects

Are there systematic differences in the ability of ATP-funded projects to accelerate the development and commercialization of technology when universities are involved in the project and when they are not? We addressed this question by asking each contact person to provide a 7-point Likert-scale (7 denoting strong agreement and 1 denoting strong disagreement) response to two statements.

The first statement posed to the lead participant assessed whether potential new applications of the technology being developed had been recognized over the course of the project. Ordered probit estimates for this question were for the most part insignificant; column 1 of Table 7 shows a minimal specification of the model. It may be that the generation of new applications from a project in process cannot be attributed to any particular individual project characteristics and is essentially unpredictable regardless of the technology area. The results do however suggest that projects with a higher ATP share are more likely to develop unanticipated applications for the technology. Perhaps a higher ATP share brings greater resources for ATP monitoring or imparts on the research performers a greater leveraging effect to search for or to recognize new applications of the technology. University participation shows no impact on the generation of new technology applications.

The second statement assessed whether the lead participant—at the stage of the research reached at the time of the survey—believed that the technology would be developed and commercialized sooner than expected when the project began. The ordered probit estimates are shown in column 2 of Table 7. A number of variables are significant leading to five interesting conclusions.

1. Projects involving universities as partners are less likely to develop and commercialize technology sooner than expected, perhaps reflecting that universities are involved in more difficult projects to begin with, namely projects with a lower probability of early completion.

2. Large projects and/or projects with large lead participants are less likely to expect to develop and commercialize their technology sooner than expected compared to projects with non-profit or medium-sized lead participants. Perhaps such larger projects reveal a whole new set of research insights. To the extent that larger research budgets are associated with research projects that can stretch the frontiers of knowledge then less time will be devoted toward looking for early-on commercialization opportunities of the technology.

3. Projects with a small lead participant are less likely to expect to develop and commercialize technology sooner than expected. Recall that this group is very small firms, and this may reflect resource constraints they face in development when the project budget does not cover the full cost of making the technology commercially viable.

4. Lack of experience with a university partner reduces the expectation of early commercialization, as does university involvement, perhaps because of lack of market pressure and focus on the particular project by the university participant, or perhaps simply because some adjustment costs are included as the participants learn to work with a university.

5. Projects in information technology, chemicals, energy, and the environment, and materials are significantly more likely to commercialize earlier than expected as compared with projects in manufacturing, electronics, and biotechnology.

IV. Concluding Observations

The focus of this survey-based study of ATP-funded research projects is on universities as research partners.[16] Our analyses of the survey data allow us to set forth in this concluding section a consistent and illuminating story about their research role. Nonetheless, all of the results from the descriptive analyses and qualitative choice models presented should be interpreted cautiously given the need for theoretical foundation, understanding of causality, and increased sample size. Given the caveats, we conclude the paper by emphasizing two themes that are consistent with our data.

Universities Create Research Awareness in ATP-Funded Projects. Our first conclusion is that universities create research awareness among the research partners in the ATP-funded projects studied. The qualitative models estimated suggest that projects with university involvement, either as a research partner or as a subcontractor, are: (1) experiencing difficulties acquiring and assimilating basic knowledge for the project's progress (Table 4); and (2) also not anticipating being able to develop and commercialize technology sooner than expected when the project began (Table 7).

At one level, these two findings could be interpreted to mean that university involvement is creating research problems acquiring and assimilating basic knowledge and commercializing technology rapidly. We eschew that interpretation because projects with university involvement are less likely to terminate early compared to projects without university involvement (Table 2). We conclude, albeit cautiously, that university involvement is creating a greater awareness of research problems.

[16] We set out to develop understanding of universities as research partners, designing our survey instruments to gather information pertinent to that understanding. Now that we have the results, as the referee for our note has observed, we have several findings about the importance of the characteristics of the RJV's lead partner. In that light, and at the suggestion of the referee, we gathered additional data about the lead partners beyond the characteristics used in our original statistical analyses and reported here. The additional information did not add to the explanatory power of our models. We believe that our small sample makes impractical the idea of pursuing in the present paper the importance of detailed characteristics—beyond size and profit versus non-profit organization—of both the lead partner and all of the other partners to a RJV. We do believe the pursuit is an important one for future research.

We offer a possible interpretation of the research role of a university.[17] Universities are included (invited by industry) in those research projects that involve what we have called "new" science. Industrial research participants perceive that the university could provide research insight that is anticipatory of future research problems and could be an ombudsman anticipating and translating to all the complex nature of the research being undertaken. Thus, one finds universities purposively involved in projects that are characterized as problematic with regard to the use of basic knowledge. Because of the type of project for which a university is likely to be invited as a research partner, the research will not move faster than expected toward a commercial application of the resulting technology. Universities are more likely to partner in new technological fields where R&D is closer to science, and such fields can be more uncertain and difficult.

Research Funding Influences the Scope of the Research. We infer from the findings that projects with larger research budgets undertake research of a broader scope, as opposed to researching a narrow project in greater detail. Projects with larger budgets are less likely to commercialize their technology ahead of schedule (Table 7). That is not inconsistent with such projects attempting to foster newer frontiers of research. It is, however, also true that projects with larger budgets have fewer problems acquiring and assimilating basic knowledge (Table 4). Thus, if the larger budgeted projects are broader, the scope and breadth may address new applications (new generic technology across many industries for example) rather than fundamental basic research.

We do not speculate as to the extent to which our findings can be generalized to either other projects that are partially publicly funded, or to private sector joint ventures with and without university research interactions. As more research is conducted on this topic, the wider applicability of our observations will and should be tested.

[17] Absent baseline information about the technical difficulty of the projects or their closeness to "new" science other than technology field, this interpretation is offered cautiously.

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Table 1
Distribution of ATP-Funded Projects by Type of University Involvement

Type of University Involvement	Number of Projects	Filtered Projects	Sample Projects	Sampling Probability	Number Responding
Joint Venture	118	81	36	44.4%	29
No university involvement (jv)	47	31	9	29.0%	8
Universities involved as subcontractors (jvs)	42	28	9	32.1%	8
Universities involved as research partners (jvu)	16	11	9	81.8%	8
Universities involved as both partner and sub. (jvus)	13	11	9	81.8%	5
Single applicant	234	111	18	16.2%	18
No university involvement (s)	106	45	9	20.0%	9
Universities involved as a subcontractor (ss)	128	66	9	13.6%	9
Total	352	192	54	28.1%	47

Filtered projects are projects that have been active one year or more and are still active in the beginning of 1998.
Sampled projects were selected from the filtered project universe to ensure an equal number in each category.

Table 2
Determinants of the Probability of Early Termination
Probit Estimates: Dependent Variable = 1 if Project Terminated Early

Variable	(1) Coefficient (s.e.)			(2) Coefficient (s.e.)			(3) Coefficient (s.e.)		
D (university involvement)	-0.434	(0.258)	*	-0.537	(0.269)	**	-0.478	(0.249)	*
ATP share of funding	-1.783	(0.943)	*	-1.472	(0.957)		-1.374	(0.899)	
Time trend	-0.112	(0.082)		-0.112	(0.084)		-0.079	(0.075)	
Small lead participant	-0.716	(0.317)	**	-0.818	(0.326)	**	-0.914	(0.302)	***
Large lead participant	-0.929	(0.348)	***	-0.943	(0.351)	***	-0.848	(0.335)	***
Non-profit lead part.	-0.401	(0.466)		-0.337	(0.467)		-0.516	(0.419)	
Chi-square for 3 size vars. (prob.)	8.47	(0.037)	**	9.47	(0.024)	**	10.50	(0.015)	**
Information Technology	0.025	(0.338)		-0.074	(0.347)				
Electronics	-0.488	(0.465)		-0.478	(0.389)				
Biotechnology	-0.533	(0.455)		-0.510	(0.569)				
Chemicals, Energy, & Environ.	-0.039	(0.387)		-0.022	(0.457)				
Chi-square for 4 tech. vars. (prob.)	2.90	(0.575)		2.16	(0.675)				
Intercept	0.738	(0.655)		0.662	(0.664)		0.285	(0.569)	
Number of observations	313			312			351		
Log likelihood	-67.33			-64.42			-67.89		
Scaled R-squared	0.126			0.133			0.115		
Chi-squared (DF)	19.38 (10)			19.75 (10)			17.67 (6)		

Column (1) includes the full sample excluding projects in other manufacturing (none of which were terminated).
Columns (2) and (3) delete a single observation for a project that was terminated prior to starting.
The excluded category is a project in materials with no university participation and where the lead participant is of medium size.
Coefficient significance levels are denoted by * (10 percent) ** (5 percent) *** (1 percent).
The scaled R-squared is a measure of goodness of fit relative to a model with only a constant term, computed as
a nonlinear transformation of the LR test for zero slopes (see Estrella 1998).

Table 3
Simulation of Probability of Termination
ATP Information Technology Projects Begun in 1991

	University Involved	No University Involved
Size of Lead Participant (50% ATP share)		
Small	0.036	0.094
Medium	0.189	0.344
Large	0.042	0.106
Not-for-profit	0.081	0.179
ATP Share of funding (Medium Lead Part.)		
Zero	0.423	0.612
25 percent	0.296	0.477
50 percent	0.189	0.344
75 percent	0.111	0.228
100 percent	0.059	0.138

This simulation is based on specification (1) in Table 2.

Table 4
Determinants of Difficulty Acquiring Basic Knowledge

Variable	(1) Ordered Probit Coefficient (s.e.)			(2) Ordered Probit Coefficient (s.e.)		
Log of total project budget	-0.76	(0.36)	**	-0.68	(0.30)	**
ATP share (fraction)	-0.92	(3.00)				
D (university participant)	1.16	(0.61)	*	1.12	(0.49)	**
D (no prior experience)	1.16	(0.50)	**	0.12	(0.48)	**
Log (revenue of lead part., $M)	0.12	(0.07)	*	0.12	(0.06)	**
Non-profit lead part.	1.98	(1.22)		2.15	(1.09)	**
Information Technology	0.03	(0.64)		0.04	(0.57)	
Manufacturing	-1.17	(0.94)		-1.24	(0.92)	
Electronics	3.03	(1.07)	***	3.03	(1.08)	***
Biotechnology	0.07	(0.62)		0.06	(0.61)	
Chemicals, energy, and environ.	-0.97	(0.84)		-0.92	(0.82)	
Chi-sqaure for 5 tech. vars. (prob.)	12.7	(0.027)	**	12.8	(0.025)	**
Non-termination hazard	-0.34	(1.00)				
JVUS	-0.29	(0.75)				
Number of observations	47			47		
Pseudo R-squared	0.216			0.209		
Chi-squared (p-value)++	24.16 (.030)			23.40 (.009)		

++This chi-squared is for the joint test that all coefficients except the intercept are zero.
The categories have been collapsed from 7 to 5, using the groupings (1&2), 3, 4, 5, (6&7).
The excluded category is a project in materials with no university participant.
Coefficient significance levels are denoted by * (10 percent) ** (5 percent) *** (1 percent).

Table 5
Determinants of the Problems in the Project
Ordered Probit Estimates

Variable	Personnel-related Coefficient (s.e.)		
Log of total project budget	-0.04	(0.34)	
D (university participant)	0.89	(0.54)	*
Log (revenue of lead part., $M)	0.15	(0.08)	*
Non-profit lead part.	-0.57	(1.27)	
Information Technology	1.26	(0.77)	
Manufacturing	1.30	(1.09)	
Electronics	1.84	(1.26)	
Biotechnology	1.53	(0.86)	*
Chemicals, energy, and environ.	1.61	(0.93)	*
Chi-square for 5 tech. vars. (prob.)	4.61	(0.465)	
Number of observations	44		
Pseudo R-squared	0.244		
Chi-squared (p-value)++	14.51 (.105)		

++This chi-squared is for the joint test that all coefficients except the intercept are zero.
The excluded category is a project in materials with no university participant
Coefficient significance levels are denoted by * (10 percent) ** (5 percent) *** (1 percent).

Table 6
Percentage of Unproductive Research Time and Cost
Ordered Probit Estimates

	(1)			(2)		
Dependent Variable	Research Time			Research Cost		
Variable	Coefficient (s.e.)			Coefficient (s.e.)		
D (university participant)	0.41	(0.39)		0.98	(0.41)	**
Log (revenue of lead part., $M)	-0.16	(0.06)	***	-0.14	(0.06)	**
Non-profit lead participant	-1.35	(0.83)		-1.08	(0.83)	
Information Technology	-1.07	(0.50)	**	-0.77	(0.51)	
Manufacturing	-1.73	(0.73)	**	-1.73	(0.74)	**
Electronics	2.19	(0.98)	**	2.87	(0.99)	***
Biotechnology	-0.21	(0.53)		-1.26	(0.57)	**
Chemicals, energy, and environ.	1.31	(0.62)	**	0.93	(0.62)	
Chi-square for 5 tech. vars. (prob.)	20.8	(0.001)	***	19.7	(0.001)	***
No. of observations	42			42		
Pseudo R-squared	0.162			0.172		
Chi-squared (p-value)++	24.86 (.002)			23.95 (.002)		

+The dependent variable takes on the values 0,5,10,15,20,25,30 percent.
++This chi-squared is for the joint test that all coefficients except the intercept are zero.
The excluded category is a project in materials.
Coefficient significance levels are denoted by * (10 percent) ** (5 percent) *** (1 percent).

Table 7
Performance Determinants
Ordered Probit Estimates

Dependent Variable	(1) New applications of technology developed+			(2) Commercialized sooner than expected		
Variable	Coefficient (s.e.)			Coefficient (s.e.)		
Log of total project budget				-0.95	(0.26)	***
ATP share (fraction)	2.97	(1.68)	*			
D (university participant)	0.02	(0.34)		-0.78	(0.37)	**
D (no prior experience)				-0.98	(0.44)	**
Small lead participant				-1.52	(0.57)	***
Large lead participant				-1.96	(0.65)	***
Non-profit lead participant				0.39	(0.65)	
Chi-square for size vars. (prob.)				15.04	(0.002)	***
Information Technology				1.08	(0.43)	**
Manufacturing						
Electronics						
Biotechnology						
Chemicals, energy, and environ.				1.13	(0.65)	*
Materials				1.69	(0.52)	**
Chi-square for tech. vars. (prob.)				12.49	(0.006)	***
No. of observations	47			47		
Pseudo R-squared	0.024			0.167		
Chi-squared (p-value)++	3.29 (.193)			28.05 (.001)		

+The dependent variable takes on only six values because one of the cells (y=3) is empty.
++This chi-squared is for the joint test that all coefficients except the intercept are zero.
The excluded category in column 2 is a project where the lead participant is of medium size.
Coefficient significance levels are denoted by * (10 percent) ** (5 percent) *** (1 percent).