Barriers Inhibiting Industry from Partnering with Universities: Evidence from the Advanced Technology Program

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Abstract:

This paper describes a small, unique set of project data that was assembled as part of a larger study on universities as research partners. Herein, we summarize, to the extent possible, our interpretation of what the project data reveal about barriers, intellectual property (IP) concerns in particular, inhibiting industry from partnering with universities.

Keywords: research and development | intellectual property | research joint ventures (RJVs) | Advanced Technology Program (ATP)

Article:

1. Introduction

There is a long and well-documented history of industry/university research relationships. In Europe, such relationships can be traced at least to the mid- to late-1800s and in the United States to at least the industrial revolution. Hounshell (1996) and Rosenberg and Nelson (1994) provide excellent historical overviews of the evolution of these associations. In recent decades, the nature of such relationships has become more formal through the formation of explicit research joint ventures and partnerships.

It is generally accepted, at least in the United States, that research partnerships are a critical strategic response to global competition.[1] The Council on Competitiveness (1996) in its recent policy statement, *Endless Frontiers*, *Limited Resources: U.S. R&D Policy for Competitiveness*, took the position that (1996, pp. 3-4), "R&D partnerships hold the key to meeting the challenge of transition that our nation now faces" and industry will increasingly rely on universities to ensure the success of the research being undertaken. Relatedly, Mowery (1998, p. 646), commenting on structural changes in the U.S. innovation system, noted that a major element of

We appreciate the comments and suggestions from William L. Baldwin, Donald Siegel, and the participants at the special issue workshop at Purdue University, June 9–11, 2000, on an earlier version of the paper.

[1] For a review of the theoretical and empirical literature on research partnerships, see Hagedoorn, Link, and Vonortas (2000).

structural change is “increased reliance by U.S. firms on sources of R&D outside their organizational boundaries, through such mechanisms as ... collaboration with U.S. universities....”

In the United States, the number of new, formal research joint ventures (RJVs) formed under the National Cooperative Research Act (NCRA) of 1984 and its amendment the National Cooperative Research and Production Act (NCRPA) of 1993 has been cyclical, reaching a peak in 1995, falling for three years, and just now beginning to increase again (Brod and Link, forthcoming). However, the percentage of RJVs involving at least one university as a research partner has generally increased since 1985, as illustrated in Figure 1.[2,3]

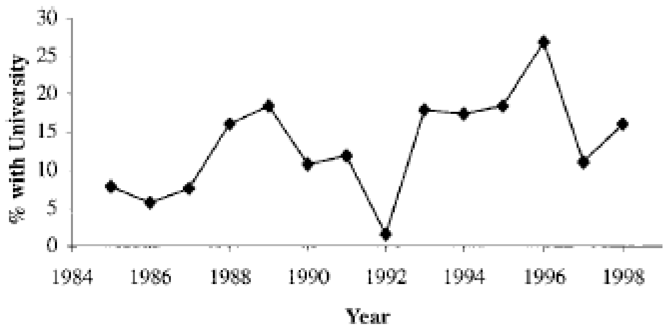

Figure 1. Percent of RJVs with at least one university.

The trend showing an increase in RJVs with university partners is not surprising given the claim by the Council on Competitiveness that university presence helps to ensure the partnership’s research success. Rosenberg and Nelson (1994, p. 340) make a similar claim, “What university research most often does today is to stimulate and enhance the power of R&D done in industry.” Hall, Link, and Scott (2000, p. 19) conclude from their project-based study of universities as research partners that universities create research awareness among the research partners of the joint venture:

> Universities are included (e.g., invited by industry) in those research projects that involve what we have called “new” science. As such, it is the collective perception of the other research participant(s) that the university could provide a research insight that is more anticipatory of future research problems that might be encountered and could thus take on the role of an ombudsman to anticipate and translate to all concerned 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.

Given the research productivity-enhancing effects of such partnerships, the trend in Figure 1 may well continue and perhaps even intensify. However, there is another issue implicit in Figure 1,

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[2] Of the 741 RJVs filed by the end of 1998, 111 had at least one university involved as a research partner. In addition, the average number of university members as a share of the total number of members in an RJV has steadily increased over time.

[3] The estimated slope coefficient from a linear regression on time of the percentage of RJVs with at least one university partner is positive and significant. These results and those from other specifications are available from the authors.

and that issue serves to motivate this paper. Whereas universities are research partners in about 15 percent of all RJVs — at least all RJVs that are registered under the NCRA and NCRPA and made public in the *Federal Register* — the vast majority of research partnerships do not involve a university. Was university research participation in these projects simply not warranted because of the nature of the research? Or, was a research relationship with a university sought, but institutional barriers inhibited or even prevented the research partnership from coming about?[4]

In Section 2 we describe a small, unique set of project data that was assembled as part of a larger study on universities as research partners in projects funded by the Advanced Technology Program (Hall, Link, and Scott, 2000). In Section 3, we summarize, to the extent possible, our interpretation of what the project data reveal about barriers, intellectual property (IP) concerns in particular, inhibiting industry from partnering with universities. Finally, in Section 4 we offer some policy observations in light of our findings.

2. The advanced technology program and the program's project data

The Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-418) not only changed the name of the National Bureau of Standards to the National Institute of Standards and Technology (NIST) and broadened its scope of responsibility, but also it facilitated the ability of Congress to enact a so-called direct competitiveness program, the Advanced Technology Program (ATP). The American Technology Preeminence Act of 1991 (P.L. 102-245) later clarified the mission of the ATP.

The stated goals of the ATP are to assist U.S. business in creating and applying the generic technology and research results necessary to:

1. commercialize significant new scientific discoveries and technologies rapidly; and
2. refine manufacturing technologies.

The ATP was also designed to enhance the competitiveness of industry. The enabling legislation is explicit about that objective:

> The ATP . . . will assist U.S. businesses to improve their competitive position and promote U.S. economic growth by accelerating the development of a variety of pre-competitive generic technologies by means of grants and cooperative agreements.

Towards this goal, ATP was mandated to enhance competitiveness by underwriting selected research projects. Thus by design, the ATP represents a program for direct funding of private-

[4] We realize that this is not a new question. The National Science Foundation hosted a one-day Workshop on Intellectual Property Rights in 1981. "The purpose of the workshop was to find out whether intellectual property issues were inhibiting cooperative research and, if so, how" (National Science Board, 1981, p. 275). The Office of the General Counsel concluded that patents are not always an effective mechanism to resolve intellectual property rights issues.

sector research through public-sector financial resources.[5] The first ATP awards were made in April 1991.

For this study, 38 projects funded by the ATP between 1993 and 1996 were considered.[6] This group of projects was randomly selected from the population of all completed ATP projects during that time period that were either single participant projects or one of four categories of joint venture research projects: without a university as a research partner, with a university(ies) as a research partner, with a university(ies) as a subcontractor, with a university(ies) as a research partner and a university(ies) as a subcontractor.

A complete description of the sample selection process is in Hall, Link, and Scott (2000). The sample in that paper included not only the 38 projects used here, but also 9 single-participant projects with a university(ies) as a subcontractor. Information about IP barriers was not available for those projects; hence, they could not be used in the present study.

With the assistance of the ATP, information was collected about the members of each research project and the project's funding characteristics. Also, the lead participant in each project was identified; that participant was contacted in advance about the nature of the study, asked to respond to a brief survey instrument, and assured that individual responses would remain anonymous.

We are sensitive not only about the smallness of this sample but also about the fact that the ATP-funded research projects are not necessarily representative of the population of all research undertakings, whether they be collaborative or not. Accordingly, we emphasize up front that the patterns in our project data as well as our conclusions should be interpreted (and generalized) with the utmost caution. However, to date, there is a void of research that has attempted to identify systematically barriers that inhibit industry from participating with universities in research projects, ATP-funded or otherwise.[7] Thus this research is exploratory in its nature, sample size issues aside, and should be interpreted as such.

3. Analysis of the survey data

The focus of this study is to investigate whether there are identifiable barriers — intellectual property rights related barriers in particular — that inhibit firms from partnering in research with a university(ies), and if so, to consider if such barriers are relatively more common in particular types of research projects. The issue of intellectual property vis-à-vis the relationship between firms and universities has precedence in the literature. According to Rappert, Webster and Charles (1999, p. 873), for example, drawing in part on the work of Feller (1990):[8]

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[5] See Link and Scott (forthcoming) for an economic rationale for the ATP as a direct funding program. See also Link (1999) for a discussion of the ATP within the broader context of public/private partnerships in the United States.
[6] Information about each project is in the Appendix at the end of the paper.
[7] See Cohen, Florida, and Randazzese (forthcoming) for a discussion of intellectual property protection mechanisms that successfully facilitate industry-university collaboration.
[8] These authors go on to say, as emphasis for understanding the environment associated with the imposition of IPRs, "[w]hile the university-industry interface might be a key factor in promoting innovation, the complex and varied nature of that interface needs to be understood and explored" (p. 875).

> Since university research is often portrayed as a public good (e.g., characterized by free circulation), the spread of IPR [intellectual property rights] protection into university R&D activities has attracted considerable attention. Where once industry benefited from exchange systems with academia based upon transactions such as informal barter relationships, those in industry now find universities seeking contractual, exchange-value-based relationships.

Brainard (1999, p. 9), is more explicit about the differing objectives of industry and universities regarding intellectual property. And, it is these conflicting objectives that cause potential research relationships to fail, or perhaps never to begin in the first place:

> The goal of business and universities in producing and protecting intellectual property is innovation for the production of revenue. Beyond this ultimate shared goal, the interests of universities and businesses diverge. Universities value intellectual property not only as a revenue-producing resource, but also as a tool in the advancement and dissemination of knowledge. These divergent interests can result in conflicts . . . .

Hall (1999, p. 3) also discusses this issue, which she refers to as the "two worlds" of research and development:[9]

> [W]e might expect particular tensions to arise in settings where the conventions of one world (private industry) come up against the conventions of another (public R&D and university science).

Lead participants in the 38 projects studied were asked a variety of direct-response and open-ended questions from which we judged if intellectual property issues were an insurmountable barrier or a significant stumbling block with regard to a university being included as a research partner in the project.[10] Thirty-two percent of the survey respondents noted that IP issues were indeed an insurmountable barrier. Representative remarks from lead participants, in projects without university involvement, who reported that IP barriers prevented the partnership with a university are:[11]

> In general, companies such as ours believe that we own the intellectual property developed for us under sponsored research. This view is often not shared by potential university partners.
>
> IP is often a stumbling block for collaborations because many universities want to publish results prior to IP protection, and sometimes will not grant exclusivity of results.

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[9] See also Dasgupta and David (1992).

[10] The survey questionnaires are available from the authors. Each project has a designated lead participant for reporting purposes to the ATP.

[11] Siegel, Waldman, and Link (1999) report that the most significant barrier to industry/university technology transfer is a lack of understanding (on the part of firms and universities) regarding corporate, university, and scientific norms and environments.

> In general, the difficulties that usually prevent a successful partnership [with a university] are (1) intellectual property issues and (2) the university partner's lack of understanding of our business.

Some projects, in which intellectual property issues prevented a university from being a research partner, were nevertheless able to use a university as a subcontractor.[12] Observations from lead participants in such projects are:

> Universities feel that if their brainpower and equipment were used to develop a new technology then they should benefit financially as an industrial partner would. However, to do so they should be prepared to take an equity position in any commercial ventures derived from the technical work.
>
> University licensing offices have an overinflated view of the value they bring to the project. [They have] unrealistic licensing expectations [and] an overinflated view of the value of intellectual property.

We assembled data on several characteristics of each of the 38 ATP-funded projects in the sample. In particular, we know the total budget of each project; the amount of the total budget that is funded by the ATP and hence the percentage of each project that was ATP-funded; the proposed length or duration of each project; the size of the lead participant;[13] the organizational structure of the awardee (single participant, joint venture with no university involvement, joint venture with a university as a subcontractor, joint venture with a university as a research partner, joint venture with a university as a subcontractor and as a research partner); if the lead participant has previously been involved with a university as a research partner; and the technology class that characterizes the research of the project. More specifically, for the analysis that follows we define the following variables:

IPbar is a dichotomous variable equaling 1 if the lead participant in the project reported that there were intellectual property rights issues that created insurmountable barriers thus preventing a university from being a research partner in the project, and 0 otherwise;[14]

total is the total cost, including the ATP award for the research project, measured in thousands of dollars.

atppct is the percentage of total project cost funded by the ATP;[15]

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[12] Our data are not rich enough for us to determine if the firm first tried to include the university as a research partner, and then when that failed it included that same university, or another, as a subcontractor.
[13] Lead participants are classified by the ATP as being a small firm (less than 500 employees), a large firm (defined as a *Fortune* 500 or equivalent organization), a medium-sized firm (defined as not small or large), or a non-profit organization (such as a trade association).
[14] *IPbar* = 0 should be interpreted to mean that the research firm did not face any insurmountable IP barriers when including a university as a research partner, did face issues but overcame them, or did not require a university as a research partner in the project. *IPbar* = 1 should be interpreted to mean that a university was sought to be a research partner, but the relationship could not be finalized because IP issues could not be resolved.
[15] By statute, ATP's maximum contribution to a single applicant project is $2 million. For joint ventures of any organizational structure, ATP cannot fund over 50 percent of direct costs.

length equals the length of the research project in years;[16]

small equals 1 if the lead participant is a small-sized firm, and 0 otherwise;

medium equals 1 if the lead participant is a medium-sized firm, and 0 otherwise;

large equals 1 if the lead participant is a large-sized firm, and 0 otherwise;

nonprof equals 1 if the lead participant is a nonprofit organization, and 0 otherwise;

s equals 1 if the awardee is a single participant, and 0 otherwise;

jv equals 1 if the awardee is a joint venture with no university involvement, and 0 otherwise;

jvs equals 1 if the awardee is a joint venture with a university as a subcontractor, and 0 otherwise;

jvu equals 1 if the awardee is a joint venture with a university as a research partner, and 0 otherwise;

jvus equals 1 if the awardee is a joint venture with a university as a subcontractor and as a research partner, and 0 otherwise;

prevuniv equals 1 if the lead participant has previously been involved with a university as a research partner, and 0 otherwise.[17]

All of the above information, except for *IPbar* and *prevuniv* came from the ATP; information about *IPbar* and *prevuniv* came from the surveys.

Descriptive statistics on each of these variables are in Tables I and II. The sample of 38 projects is divided into those for which the lead participant reported an insurmountable IP barrier (12 observations), and those for which IP issues were not so characterized (26 observations). Of these 26, 13 were joint ventures with university(ies) as research partners (*jvu* and *jvus*). Not surprisingly, none of these joint ventures reported an insurmountable IP barrier to partnering (see Table II).[18] Thus some of our subsequent analysis focuses only on the 25 observations for joint ventures without university partners (*jv*, *jvs*) and for single participant projects (*s*), of which 12 reported insurmountable barriers. We show descriptive statistics for this sample of 25 observations in Table I also.

We also found that all projects with a single participant who reported prior experience with a university partner reported that IP was an insurmountable barrier in partnering with universities.

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[16] There is a three-year statutory limit on single applicant projects and a five-year limit on joint venture projects.
[17] Previous involvement with a university as a research partner was defined on the survey as frequent, infrequent, or never. Here, any previous involvement is captured by the variable *prevuniv*.
[18] These 13 observations also included all the projects with a non-profit lead participant.

Thus *s* plus *prevuniv* is a perfect predictor. However, those without prior experience also occasionally encountered IP barriers, so we included all these projects in our estimating sample because they provide some information on the determinants of IP barriers.

Table I. Sample descriptive statistics

Variable	Mean	S.D.	Median	1Q	3Q	Min	Max
All projects (*N* = 38)							
Project size ($1000)	10,794	8,533	7,486	3,935	15,544	1,987	39,070
ATP share of funding	52.2%	8.0%	49.5%	49.0%	50.0%	43.7%	83.6%
Length (years	3.5	1.2	3.0	3.0	5.0	1.5	5.0
Projects excluding JVs with university partners (*N* = 25)							
Project size ($1000)	8,912	7,575	6,841	3,312	11,909	1,987	31,309
ATP share of funding	53.8%	9.5%	49.4%	49.0%	57.1%	43.7%	83.6%
Length (years	3.2	1.1	3.0	2.0	4.0	1.5	5.0
Projects with IP barriers (*N* = 12)							
Project size ($1000)	8,303	9,108	3,464	2,930	12,874	1,987	31,309
ATP share of funding	57.3%	10.3%	51.9%	50.0%	63.1%	49.0%	83.6%
Length (years	2.7	1.2	2.1	2.0	3.0	1.5	5.0

Table II. Sample descriptive statistics (binary variables)

	All projects (*N* = 38)		Projects with IP barriers (*N* = 12)		Projects with no IP barriers (*N* = 26)	
Variable	**Mean**	**Number = 1**	**Mean**	**Number = 1**	**Mean**	**Number = 1**
IP barriers? (*IPbar*)	0.316	12	1.000	12	0.000	0
Small lead participant (*small*)	0.368	14	0.417	5	0.346	9
Medium lead participant (*medium*)	0.132	5	0.167	2	0.115	3
Large lead participant (*large*)	0.316	12	0.417	5	0.269	7
Non-profit lead participant (*nonprof*)	0.184	7	0.000	0	0.269	7
Single participant (*s*)	0.237	9	0.583	7	0.077	2
Joint venture with no university (*jv*)	0.211	8	0.167	2	0.231	6
Joint venture with university as subcontractor (*jvs*)	0.211	8	0.250	3	0.192	5
Joint venture with university as partner (*jvu*)	0.211	8	0.000	0	0.308	8
Joint venture with university as partner and subcontractor (*jvus*)	0.132	5	0.000	0	0.192	5
Prior experience with a university (*prevuniv*)	0.789	30	0.917	11	0.731	19
Info. and computer systems	0.237	9	0.250	3	0.231	6
Materials	0.211	8	0.167	2	0.231	6
Manufacturing	0.132	5	0.000	0	0.192	5
Electronics	0.079	3	0.167	2	0.038	1
Energy and environment	0.026	1	0.000	0	0.038	1
Biotechnology	0.237	9	0.250	3	0.231	6
Chemicals (*chem*)	0.079	3	0.167	2	0.038	1

Table I shows that the projects encountering IP problems tend to be smaller, shorter, and have a higher ATP share of the funding. Besides the fact that joint ventures with university partners and non-profit lead participants do not encounter insurmountable IP barriers, Table II shows that such barriers are enhanced, rather than diminished, by prior experience with a university. Among the three technology classes that are more highly represented — information technology, materials, and biotechnology — IP issues as an insurmountable barrier preventing universities being a research partner are not noticeably different.

In an effort to understand more systematically when intellectual property issues are an insurmountable barrier preventing university participation as a research partner (not as a subcontractor), we considered the following exploratory model:[19]

(1) *Probability* (*insurmountable IP barrier = F(atppct*, *length*, *prevuniv*, *chem*, *small*, *large*)

where each of the variables has been previously defined, with the exception of the dummy variable that classifies projects in chemicals technology (*chem* = 1, and 0 otherwise). Equation (1) was estimated as a probit model using *IPbar* as the dependent variable and the estimates are shown in Table III. We consider 3 samples of observations, all of which give the same general conclusions. Column (1) contains estimates for the whole sample, column (2) for the sample of observations excluding those with non-profit lead participants, and columns (3) and (4) for the sample of observations excluding joint ventures with university participants (*jvu* and *jvus*).

Table III. Predicting the probability of insurmountable IP barriers

Number of observations	**(1)** **38**		**(2)** **31**		**(3)** **25**		**(4)** **25**		**(4)** **D(prob)**
ATP share	27.8	(13.2)**	25.2	(12.9)*	22.4	(12.3)*	23.7	(12.3)*	4.43
Length of project	–1.59	(0.77)**	–1.40	(0.74)*	–1.57	(0.79)**	–1.24	(0.69)*	–0.23
Prior university experience	5.35	(2.80)*	4.95	(2.72)*	4.39	(2.62)*	4.81	(2.63)*	0.90
Chemicals	4.44	(1.84)**	3.89	(1.80)**	3.77	(1.82)**	3.36	(1.70)**	0.63
Small lead participant					–1.51	(1.51)			
Large lead participant					–1.41	(1.37)			
Intercept	–15.2	(8.4)*	–13.9	(8.2)*	–10.1	(8.2)	–13.3	(8.0)*	
Log likelihood	–9.67		–9.17		–7.80		–8.49		
Pseudo r-squared	0.673		0.663		0.668		0.627		
Chi-squared for zero coefficients (p-value)	28.1	(.000)	23.0	(.000)	19.0	(.004)	17.6	(.001)	

Notes: Coefficient estimates are from the cumulative normal probability that partnering encountered insurmountable IP barriers.
Standard error estimates are shown in parentheses. *, **, *** denote significance at the 10%, 5%, and 1% level respectively.
Specification (2) omits 7 observations where the lead participant is non-profit because for these observations the absence of IP barriers is predicted perfectly.
Specifications (3) and (4) omit 6 additional observations for joint ventures with university partners; these observations also predict the absence of barriers perfectly. All of the non-profit participants are also joint ventures with university partners.
In specification (4), the average (over the sample) derivative of the probability with respect to the variable is shown in the last column.

Our first finding is that the size of the lead participant does not help to predict the presence of insurmountable IP barriers (column (3))in the presence of the other variables, so our preferred specification is that in columns (1), (2), and (4), all of which have similar findings. This last fact means that the results in column (1) are not simply because of the fact that joint ventures with

[19] This specification was motivated in large part by the availability of data.

university participants that have not encountered IP barriers or have overcome them (the group we excluded in columns (3) and (4)) are different in other ways from the rest of the sample.

Focusing now on column (4) in Table III, we see that in spite of the small sample, the overall model is significant in predicting the probability of encountering IP barriers to partnering and that it has a pseudo R^2 of just over 60 percent. Difficulties in negotiating IP among the partners are associated positively with ATP's share in the project, the lead participant's prior experience with university partnering, and being a project in the chemicals industry, and negatively with the length of the project. We will discuss each of these factors in turn.

First, as the percentage of project costs that is funded by the ATP increases, the probability that IP issues will create insurmountable barriers inhibiting a university from joining the project as a research partner also increases. The calculated partial derivative of the probability with respect to this variable is quite large — 4.4. At the mean value of 54 percent, an increase in *atppct* of one standard deviation (10%) predicts that the probability of there being an insurmountable IP barrier increases by 0.44 or by 44 percent, albeit with a standard error of about 23 percent.[20]

Our interpretation is that the ATP share in project funding is an instrument that is highly correlated with the expected inappropriability or publicness of the research results. The larger the percentage of a project that a firm is willing to fund, the more the firm expects to be able to appropriate an adequate portion of the research results from that project and hence the less public the nature of the results. Increases in ATP's funding percentage, mirroring decreases in the firm's funding percentage, thus reflect research results that are expected by the firm to be less appropriable or relatively more public in nature. At the same time, these firms have been unable to reach an agreement with a university partner to do the research. As a result, it logically follows that as the percentage of funding from ATP increases the "two worlds" of R&D are increasingly in conflict, with the firm trying even harder to capture all intellectual property while the university is trying to make it public. Hence, IP issues become more noticeable and act as a barrier to the industry-university research partnership as ATP's funding percentage increases.[21] Alternatively, it is possible that ATP funding is to a certain extent substituting for the university in the cases where negotiation between the potential partners broke down because of differences over IP rights.

The second finding in column (4) of Table III is that IP barriers are greater the shorter the length of the project. Again, the partial effect is large. As project length increases from the mean of 3.17 years to 3.67 years (approximately six months), the estimated probability of there being an insurmountable IP barrier decreases by 11.5 percent, with a standard error of approximately 6 percent.

Our interpretation is that the length of the project is highly correlated with the uncertainty of the research findings. The longer the expected duration of the research at the time the research is

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[20] The exact effect of any stated change in an explanatory variable can be computed by the interested reader by calculating the effect on the probit index. For that procedure, use the estimated probit coefficients, the means of the variables as shown in Table I, and the stated settings for the explanatory variable in question. The computed index values can then be converted to the associated value of the standard normal probability function.

[21] And, we expect this to be the case regardless of the funding agency.

funded, the less certain the firm or the university will be as to the intellectual property characteristics of the research results. Hence, the longer the expected duration of the research project, the less likely it is that either party will face an insurmountable IP barrier because neither party is able to define meaningfully the boundaries of characteristics that the research results will have. Note that this does not rule out the possibility that unanticipated conflicts over IP rights may arise in the future, it is simply that IP barriers do not prevent the project from starting.

Our third finding is that lead participants that have been involved with universities as research partners in the past are, other factors held constant, relatively more likely to find IP issues with a university insurmountable. On average across the sample, changing *prevuniv* from 0 to 1 increases the predicted probability of insurmountable barriers by 0.9. Evidently, experience with universities as partners does not, given the currently available IP-protection mechanisms, allow resolution of IP issues. Instead, the experience appears to make industry aware of the insurmountable barriers that exist given current institutional arrangements for protecting intellectual property.[22]

Alternative specifications of equation (1) were examined (not reported here). In all cases, the only technology effect that was significant was that for projects in chemicals technology, thus the other technology class dummies were deleted. Other researchers have shown that patent protection is especially important to firms in the chemicals industry.[23] Hence, the university would also find it financially attractive to have ownership rights in this technology area, and thus conflict arises. On average across the sample, projects involving chemicals technology have a probability of insurmountable IP barriers that is higher than the probability for the other technologies by 0.63. However, we remind the reader that there are only 3 chemical projects in our sample, so this result for the present sample is surely a tentative one for samples in general.

As we discussed earlier, the best predictor of insurmountable IP barriers to partnering with a university was to be one of those projects that went ahead as a single participant project or as a joint venture without a university participant. Thus, the most important finding may be that there are projects funded by ATP where the participants may have desired university cooperation but found that they could not reach agreement on intellectual property issues.

4. Concluding observations

We interpret our findings from this exploratory investigation on two levels. At one level, we have demonstrated that IP issues between firms and universities do exist, and in some cases those issues represent an insurmountable barrier which prevents the sought-after research partnership

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[22] As we have noted, there are institutional constraints on ATP's share of total project funding and on project duration. A careful reader might reasonably conclude that the strong effects for ATP's share and project length simply reflect those institutional constraints for single-participant projects versus joint ventures. However, that is not the case. Adding the variable *s*, the qualitative variable for single-participant projects, to the preferred specification with 25 observations, and even accounting for the perfect predictions when single-participant projects have previous experience with universities, the partial derivative for each variable can be estimated. The partial derivative for *s* is not significant, while the remaining partial derivatives tell essentially the same story as reported in Table III. The signs of the partials are the same, and their magnitude and level of significance are quite similar.

[23] See, for example, Cohen, Nelson, and Walsh (2000) and particularly the references therein to Levin *et al*. and Mansfield.

from ever coming about. Such situations have a greater likelihood of occurring when the research is expected to lead to less appropriable results that thus have a relatively greater degree of publicness and when the expected duration of the research is relatively short term and is thus more certain in terms of the characteristics of the research findings.

Table IV summarizes these findings. It shows two panels, one for lead participants with no prior university partnering experience and one for those with prior experience. Across the top of the 2×2 matrix we segment the research as being either appropriable or inappropriable (where inappropriability is an increasing function of the percentage of the research cost that is funded by the ATP). Along the left of the matrix we segment the results as being either certain or uncertain (where uncertainly is an increasing function of the length of the research project). Within each cell of the matrix we have simulated the probability of there being insurmountable IP barriers using the probit estimates in column (4) for projects that are not in chemicals, with inappropriability/appropriability defined for purposes of these calculations as +/– one standard deviation from the mean of *atppct*, and uncertainty/certainty defined for purposes of these calculations as +/– one standard deviation from the mean of *length*.

Table IV. Probability of insurmountable IP barriers by type of research results

		Research results	
		Appropriable (low ATP share)	**Inappropriable (high ATP share)**
		No Prior University Experience	
Results of research	Certain (short projects)	0.0000	0.2173
	Uncertain (long projects)	0.0000	0.0000
		With Prior University Experience	
Results of research	Certain (short projects)	0.3160	0.9997
	Uncertain (long projects)	0.0000	0.8760

Notes: These predicted probabilities are based on the estimates in specification (4) of Table III, for projects in industries other than chemicals. The variables for ATP share and the length of the project have been set to their mean +/– one standard deviation.
Being a non-profit lead participant or a joint venture with a university participant predicts the lack of IP barriers perfectly. These observations have not been used for the predictions in this table, which is based only on the 25 observations in column (4) of Table III.

The simulated probabilities provide an interesting descriptive conclusion. First, the probabilities are much higher when the lead participant has prior experience partnering with a university, so that they are aware of the difficulties they may encounter. Second, the probability that insurmountable IP barriers will arise between a firm and a university in terms of partnering are greatest when the intellectual property characteristics of the research are certain and the ability of the firm to appropriate such results is least. Further, the probability of barriers is least when the IP is appropriable yet uncertain. The appropriability of the IP implies less publicness, and then less tension between the "two worlds." Regarding the uncertainty, the evidence in our small sample supports the possibility that, other things being the same, when neither party can define meaningful boundaries for any resulting IP, IP is less likely to be an insurmountable issue, although we recognize that is not logically inevitable. The remaining probabilities in Table IV show the intermediate cases where the two effects of publicness and of uncertainty are to an extent offsetting, although it is clear that appropriability (as measured by the ATP share) is a more important predictor than project length.

At a second and broader level, there is some policy relevance to our findings. From other investigations, there is evidence to conclude that ATP funding is overcoming a *market* failure; in the absence of such funding the research is not likely to have occurred.[24] However, as previously noted in the introduction, Hall, Link, and Scott (2000) have found that a university participating in a research partnership can take on the important role of an ombudsman to anticipate and translate to all involved the complex nature of the research being undertaken. Thus, in such desired situations, as we have shown here, there remains an element of *government* failure. The government has not provided appropriate legal infrastructure. Firms and universities, in an effort to pursue their own research strategies in their separate worlds, are unable to partner because of limitations of the intellectual property protection mechanisms that are currently available.[25]

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[24] See Link and Scott (forthcoming) and Link and Scott (1998).

[25] At one level, the presence of insurmountable IP issues implies that existing IP protection mechanisms are inadequate given the culture clash between industry and the universities. At another, one might believe that the problem could be an insurmountable culture clash that mechanisms for IP protection could not ameliorate. A look at the initial ATP guidelines shows that in fact government may have failed to provide appropriate IP protection to facilitate university-industry partnerships for ATP projects. Technology transfer officers emphasize that a problem for universities was created by the original ATP guidelines because they required that any ATP project patents must be held by the non-university participants. The original ATP guidelines did not recognize the Bayh-Dole Act under which universities are allowed to keep the title to the inventions conceived by their employees under outside sponsorship.

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Appendix: ATP-funded projects (*n* = 38)

Project no.	Project title
91010016	Ultra-high density magnetic recording heads
91010134	Hybrid superconducting digital system
92010040	Engineering design with injection-molded thermoplastics
92010044	Genosensor technology development
93010079	Flip chip monolithic microwave integrated circuit _MMIC. manufacturing technology
94010079	Engineered surfaces for rolling and sliding contacts
94010135	Enhanced molecular dynamics simulation technology for biotechnology applications
94010178	Rapid agile metrology for manufacturing
94010228	Computer-integrated revision total hip replacement surgery
94010282	Diamond diode field emission display process technology development

Project no.	Project title
94010305	Film technologies to replace paint on aircraft
94020032	Composite production risers
94020039	Low-cost advanced composite process for light transit vehicle manufacturing
94020040	Development of manufacturing methodologies for vehicle composite frames
94020043	Low cost manufacturing and design/sensor technologies for seismic upgrade of bridge columns
94020048	Manufacturing composite structures for the offshore oil industry
94040017	Automated care plans and practice guidelines
94050006	Development of rapid DNA medical diagnostics
94050027	Integrated microfabricated DNA analysis device for diagnosis of complex genetic disorders
94050030	Diagnostic laser desorption mass spectrometry detection of multiplex electrophore tagged DNA
94050033	Automated DNA amplification and fragment size analysis
95010126	Technology development for the smart display – A versatile high-performance video display integrated with electronics
95010150	Development of closed cycle air refrigeration technology for refrigeration markets
95020008	Agile precision sheet-metal stamping
95020026	Flexible low-cost laser machining for motor vehicle manufacturing
95020036	Plasma-based processing of lightweight materials for motor-vehicle components and manufacturing applications
95020062	Fast, volumetric x-ray scanner for three-dimensional characterization of critical objects
95030018	High-performance, variable-data-rate, multimedia magnetic tape recorder
95030022	Technology development for optical-tape-based rapid access affordable mass storage (TRAAMS)
95040027	Advanced distributed video ATM network for creation, editing, and distribution
95050007	Continuous biocatalytic systems for the production of chemicals from renewable resources
95050040	Breakthrough technology for oxidation of alkanes
95080006	Real-time micro-PCR analysis system
95080017	DNA diagnostics using self-detected target-cycling reaction (SD-TCR)
95100019	Healthcare information technology enabling community care
95120015	Model-driven application & integration components for MES
95120027	Advanced process control framework initiative
96010172	A portable genetic analysis system

Note: A description of each project is available at: http://jazz.nist.gov/atpcf/prjbriefs/listmaker.cfm