Science Parks and the Academic Missions of Universities:

An Exploratory Study

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Abstract

Little is known about technology flows between universities and industry that result because of linkages between university faculty and industrial organizations located in a science park. This paper explores the influence of university-science park relationships on the academic missions of a university. Of particular interest is our finding that location matters. The closer geographically a university is to its science park research partners, the greater the probability that the university's curriculum will move away from basic research toward applied research.

JEL Classifications:

I2 Education
L31 Nonprofit Institutions
O32 Management of Technological Innovation and R&D
R1 General Regional Economics

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I. Introduction

While there is a growing body of knowledge regarding university-industry research partnerships,[1] there are few studies of university-industry strategic alliances in science parks. In this paper, we characterize, using survey data collected from a sample of major research universities, the impact of science parks on selected academic missions of a university. We then relate those data statistically to university and science park characteristics.

Surprisingly, given their long-history in the United States as well as in other countries, there is no generally accepted definition of a science park. One definition has been posited by the Association of University Related Research Parks (AURRP).[2] As stated in their *Worldwide Research & Science Park Directory, 1998* (1999, p. 2):[3]

> The definition of a research or science park differs almost as widely as the individual parks themselves. However, the research and science park concept generally includes three components:
> - A real estate development
> - An organizational program of activities for technology transfer
> - A partnership between academic institutions, government and the private sector.

"Science park" has evolved to become a generic term which refers to parks with some or all of the foregoing characteristics. Under this rubric are—and these designations are subjective—research parks with a majority of tenants that are heavily engaged in basic and applied research. As well, science parks include technology parks with a majority of tenants that are heavily engaged in applied research and development. Technology or innovation parks often house new start-up companies and incubator facilities.[4] Finally, commercial or industrial parks typically have tenants that add value to R&D-based products through assembly or packaging, rather than do R&D.

Figure 1, based on the 1998 *Directory*, the most complete directory published by AURRP to date, illustrates the historical growth in the population of U.S. science parks, as defined by the date at which each park was founded.[5] Notable in Figure 1 are the following parks: Stanford Research Park (established in 1951), Cornell Business & Technology Park (established in 1952), and the Research Triangle Park of North Carolina (established in 1959).

Few scholars or researchers have studied science parks in any systematic manner.[6] A number of studies have examined the influence of being in a science park on various aspects of firm performance (e.g., growth and R&D productivity).[7] However, in contrast to existing studies, this paper provides, in an exploratory manner, the first systematic insights into the influence of industry in science parks on the academic missions of universities.

II. Sample of U.S. Universities and the Data Collection Process

The population sample of U.S. universities selected for this study consists of the 88 academic institutions that are categorized both in the top 100 academic institutions as measured by R&D expenditures and as defined by the National Science Board (2000), and in the Carnegie extensive classification of doctoral/research universities (Carnegie Foundation 2001). Our priors were that this sample would contain a large segment of academic institutions located in or near science parks that have a research or technology park character, and that have significant interactions with park organizations. The population sample is shown in Table 1.

A brief survey was designed, pretested, and then sent electronically in 2001 to the chief academic officer's office (hereafter the provost, although we found that the provost relied upon the expertise within and without of the provost's office to complete the survey) at each of the 88 universities. The purpose of the 10 percent pretest (n=9) was to ensure that a provost could, in fact, draw upon appropriate resources to answer our survey questions in an informed manner and to ensure that questions were phrased in an unambiguous manner. Follow-up telephone surveys were made to all non-respondents.

A variety of information was requested (discussed below), but the primary goal of the survey was to collect qualitative information regarding the provost's perception of the impact of the university's involvement with science parks on the following six academic missions:[8]

- research output, measured in terms of publications
- research output, measured in terms of patents
- extramural research funding
- applied versus basic nature of the curriculum
- placement of doctoral graduates
- ability of the university to hire preeminent scholars.

Motivating this inquiry is not only the conspicuous void of information about science parks in general and about technology flows from organizations into universities in particular, but also the need to understand how those flows affect fundamental academic behavior. Nelson (2001), for example, has asked if universities can take on the role of "commercial enterprises" (e.g., licensing and patenting) without jeopardizing their more traditional roles such as their commitment to publish in the public domain and contribute to public science.

We received 47 responses (electronic and telephone), representing an initial response rate of 53.4 percent. However, 18 universities responded that they currently have no relationship with a science park and that the survey was therefore not relevant to them. Our final sample, which is analyzed in this paper, consists of the remaining 29 of the 47 responding universities, representing an overall usable response rate of 33.0 percent. Each of the 29 science parks is either a research park or a technology park, using the taxonomy above.

Table 2 shows the distribution of responses to statements about the influence of science parks on the academic missions of the university. Two general patterns are clear from the distribution of responses. First, there is more agreement than disagreement (e.g., more 4 and 5 responses than 1 and 2 responses) that involvement with a science park positively affects the research output and extramural research funding of universities. Second, there is more disagreement than agreement that such involvement affects the placement of doctoral graduates and improves the ability of the university to hire preeminent scholars.

III. Quantitative Analysis of the Impact of Science Parks on the Academic Missions of Universities

To address the general question of how a science park relationship affects the academic missions of a university, we estimated six ordered probit models using the data collected from our survey. Each model was specified to explain inter-university differences in the extent to which provosts agreed or disagreed with the academic mission statements referenced in Table 2. The extent of agreement is modeled as a function of characteristics of both the university and the science park with which the university is affiliated.

Our models initially focused on the same set of independent variables as represented in the model:

(1) $$academic\ mission = f\,(relationship, mileage, rd, \mathbf{X})$$

where *academic mission* represents each provost's response to each of the six academic mission statements, and where the independent variables will be discussed below. Thus, we estimated six versions of equation (1), one corresponding to each survey statement summarized in Table 2.[9]

Regarding the independent variables in equation (1), *relationship* dichotomizes the structure of each university's relationship with its science park. The variable *formal* equals one when the relationship is formal, and it equals zero if it is informal. Two questions on the survey quantify this: "Does your university have a *formal* relationship with a science park? (By "formal" we intend any institutionally recognized arrangements, such as contractual arrangements of various sorts between your university and the science park.)"[10] Or, "Does your university have an *informal* relationship with a science park? (By "informal" we intend individual rather than institutional relationships, for example, contract research between faculty members and the science park that is not contracted through the university but treated as individual consulting.)"[11] We hypothesize that a formal relationship between a university and a science park leads to greater control over the interaction between faculty and the organizations in the park, much like in a centralized decision-making firm. Thus, where formal relationships exist the university may be able to exercise greater influence over the entrepreneurial direction that faculty take and how organizations in the park interact with the university as a whole. To the extent that a formal relationship overcomes barriers to faculty-organization interactions, it may reveal itself as greater faculty research output, greater placement of doctoral graduates, and a greater ability for the university to hire preeminent scholars.

The variable *mileage*—the miles between a university and its associated science park—quantifies the geographical relationship between the university and the science park.[12] Adams and Jaffe (1996) suggest that communication costs related to collaborative R&D activity increase with distance. Wallsten (2001) shows that geographical proximity to other successful innovative firms, as evidenced by the firm receiving a Small Business Innovation Research (SBIR) award, is associated with a firm's own success. These works, as well as the works of Feldman (1999), Feldman and Lichtenberg (2002), and Adams (forthcoming) motivate the inclusion of the variable *mileage*; we hypothesize that the closer a science park is to the university the more innovative the university. In the context of our model, *mileage* should thus enter negatively in the research output and extramural research equations. We also expect it to enter negatively in the curriculum equation, expecting a closer science park to have a bigger impact on a university's applied research since that is the research area common to both the university and the organizations in the park.

The variable *rd* is a scale variable, distinguishing universities in terms of their total research and development budget in millions of dollars.[13] Following Cohen and Levinthal (1989), we conjecture that more R&D-active universities may have a greater capacity to absorb the knowledge gained through research relationships with organizations in a science park. Thus, we hypothesize that such universities will benefit, in a research sense, relatively more from a relationship with a science park, and this absorption will show itself in more basic research and related research output.

Vector **X** controls for other university and firm characteristics. Two technology dummy (i.e., set to equal either one or zero) variables are included in the empirical specifications. Each provost was asked on the survey what technology(ies) are being investigated by faculty involved in research with science park organizations. The variable *dIT* equals 1 if information technology was mentioned, and *dbiotech* equals 1 if biotechnology was mentioned. Multiple technologies were generally mentioned; however, no significance was given to the order in which they were mentioned.

Provosts were also asked to approximate the percentage, *perinresrch,* of faculty who are routinely involved in research with science park organizations. That percentage is a scale variable approximating the proportion of faculty who could be the recipients of a reverse knowledge flow from industry into the university. The reverse flow of knowledge could have an impact on the university's academic missions.

The variable *agepark* is the age of the science park with which each university interacts, measured as the number of years between the time of the survey (in late 2000 with telephone follow-ups well into 2001) and the year that the named science park was formed.[14] This variable is designed to control for the development over time of park organizations with which the university could interact as well as the development of the quality of the interactions—a process that takes time. However, it is an imperfect control for this purpose, although no better information is available, since a park may not begin to have organizations enter immediately upon its formation.

In addition to the university and park characteristics described above, we also control for response bias. As seen in Table 3, the sample of 29 responding and reporting universities does not perfectly mirror the population sample of 88 universities in terms of the selected key characteristics. To control for response bias, we estimated the probability of responding and completing the survey, that is, the probability of selection into the sample of 29, *prob8829*.[15] That probability is a control variable in equation (1).[16]

The left-hand side variable in equation (1) is a Likert-scale response variable; hence, the appropriate statistical technique is the ordered probit model. To assess the determinants of inter-university differences in the impact of science park relationships on the academic missions of universities, six ordered probit models were estimated and the econometric results are in Table 4.

Ceteris paribus, universities with a formal relationship with a science park realize greater benefits from that relationship as quantified through increased publication and patenting activity, greater extramural funding success, and through an enhanced ability to hire preeminent scholars.

The closer geographically a university is to the science park, *ceteris paribus*, the greater the influence of park tenants on the applied versus basic research nature of the university's curriculum, and the greater the ability of the university to place its doctoral graduates. The finding about the applied research curriculum is revisited below.

The total R&D budget of the university, *rd*, enters significantly in three cases. It enters positively in the patenting equation meaning that, *ceteris paribus*, more R&D-active universities have their patenting activity positively influenced by their association with a science park, supporting the hypothesis about absorptive capacity. It enters negatively in the extramural funding equation, as well as in the hiring equation. We interpret the latter two findings to suggest that the R&D activity of the university, rather than its science park affiliation, drives its academic reputation as reflected through enhanced funding and hiring. The effect of *rd* is explored further below.

The results in Table 4 also suggest (keeping in mind the caveats associated with *agepark*) that older parks have an applied influence on the university's research curriculum, perhaps also explaining the positive effect of age on patenting. Older parks are also more likely to have a positive influence on the hiring of preeminent scholars. The percentage of faculty engaged in university/science park activities, which like *rd* is a scale variable, also enters significantly in the publications equation.

The probability of responding to the academic mission statements, *prob8829*, enters significantly in the publications model, the patents model, and the extramural research model.

Finally, as shown in Table 5, we experimented with alternative specifications of the ordered probit models by selectively deleting insignificant and marginally significant variables. Our intention was, given the small size of our sample, to examine the robustness of our findings. Table 5 shows what we call the parsimonious specifications of the models. The results show the robustness of the signs and significance for the variables remaining in the parsimonious specifications.

IV. Interpretation of Results and Conclusions

Universities seek external research relationships in an effort to enrich both the knowledge in their research base and the financial value of that knowledge. Herein, we explored how university research relationships with clusters of industrial firms in a science park affect six academic missions.

While our sample is relatively small and the information collected from university provosts is qualitative, this study is, to our knowledge, the first to address such impacts in a systematic manner.

The statistical relationships that we found are interesting for a general understanding of science parks and associated knowledge flows. However, the relationships also show how universities that are considering establishing a science park might benchmark their planned activities and structure their relationship with their science park to control the influence of the relationship on academics at the university. Our survey did not apply to 18 of the 47 universities that returned our survey. Five of those 18 universities reported that they are currently planning a science park or are in the process of building one. While we may not see a resurgence of the creation of new science parks like we saw in the mid- to late 1980s, as shown in Figure 1, our survey data and informal discussions with science park directors suggest that the science park phenomenon is again on the rise. As university administrators deal with collaborative research relationships in science parks, our results suggest the following expectations.

First, the organizational nature of the university-park relationship is important. Our measures of a formal versus an informal relationship apparently capture important differences in how universities form a research relationship with their science park. When the relationship is formal, specific impacts will follow including enhanced research output (e.g., publications and patents), increased extramural funding, and improvements in hiring capabilities.

Second, proximity of the science park to the university has an impact on various aspects of the university's academic mission. Other factors held constant, a science park located on or very close to the university campus confers greater employment opportunities for doctoral graduates. But, this nexus also has a curricular influence by causing a more applied research curriculum other things being the same.[17]

Third, *ceteris paribus*, more R&D-active universities are more likely to report that their interaction with science park organizations positively affects their propensity to patent. They are less likely to report science park effects on their extramural funding activity or on their ability to hire preeminent scholars. The R&D activity within the university in considered in more detail below.

Fourth, as measured by the percentage of faculty, the intensity with which university faculty are engaged in research with science park organizations appears to have little measurable impact on the effect of science parks on the academic missions of universities except on publications.

Fifth, the influence of university-park research interactions may change over the life of the interaction. Over time, the impact that science parks have on academic missions changes. Initially, that impact may not influence patenting activity or curriculum, but over time it will. Similarly, over time the reputation of the science park will confer a hiring advantage to the university, *ceteris paribus*.[18]

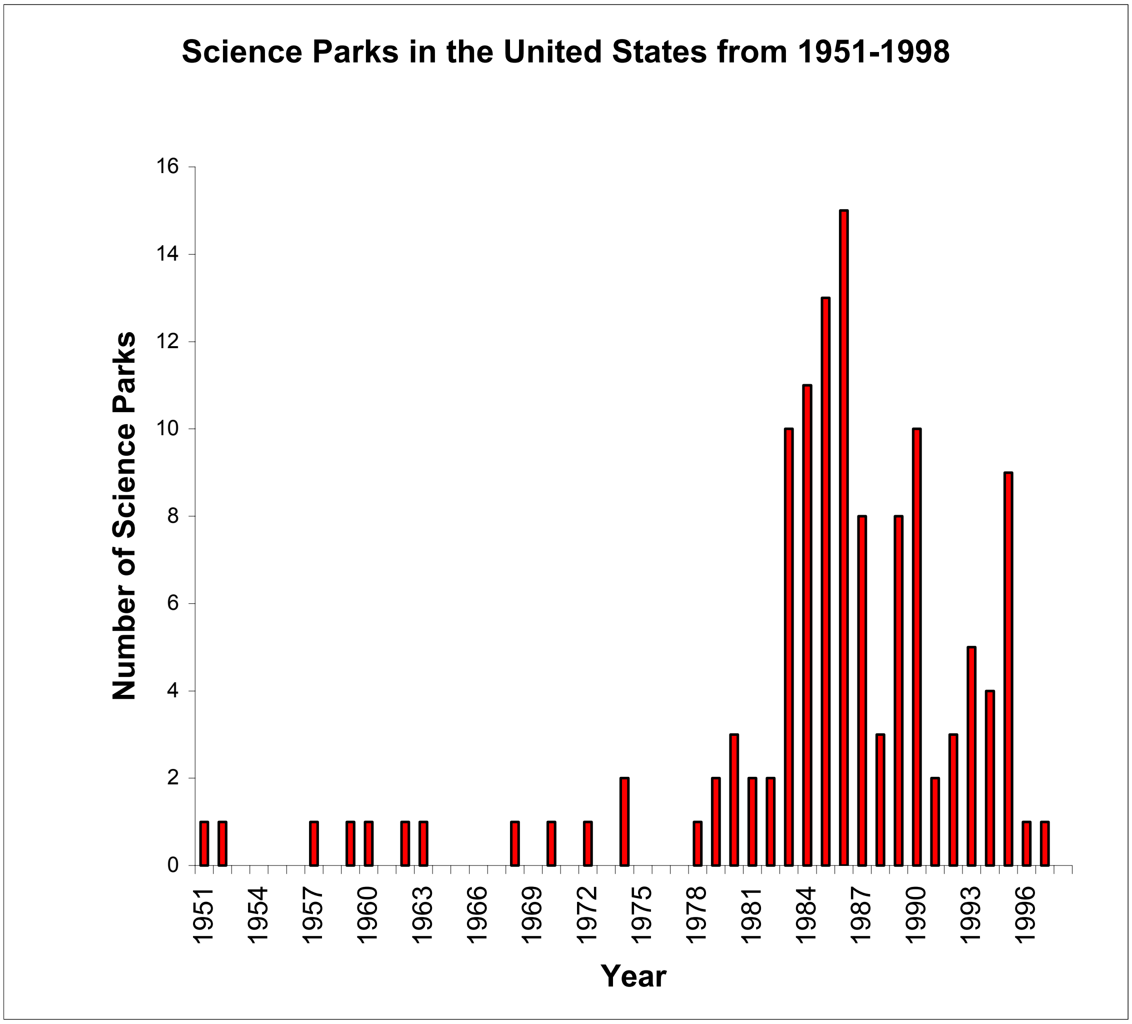
Reemphasizing the caveats associated with this study, namely that we rely on the provosts' perceptions of effects (rather than time-series data about the effects) and that our sample is small, the results in Table 4 may nevertheless be useful for guiding aspects of university decision making. The results may inform the decision making of universities that have science parks and are trying to understand the full extent of the university-park relationship. Also, the results may inform universities that are contemplating establishing a science park or planning one. We illustrate this below with two simulated examples, both focusing on the effect of a university's involvement with a science park on the applied nature of the university's research curriculum. That dimension of curricular focus has gained attention in recent years. As noted previously, Nelson (2001) has warned that as universities take on commercial activities, often in conjunction with industry, their commitment to public science may be endangered. Stephan (2001) as well has noted that there is the potential that technology transfer activities—likely to occur from university/science park interactions—will divert faculty away from students and curriculum and towards commercial activities such as the quest for extramural research funding. If such funding comes from industrial firms, then it is reasonable to be concerned that commercial influences will spill over to influence the character of the university's research and hence its research curriculum.

First, consider a university that has an ongoing relationship with organizations in a science park; consider also the ordered probit results presented in Table 4 for the applied research curriculum mission of the university. Using those estimated coefficients, we set selected variables as noted in Table 6 and then iterated over alternative values of *rd*. In the sample, the range of *rd* is \$81M to \$483M, with a mean of \$207M. As seen in Table 6, for the mean value of *rd*, about \$200M, the probability of a neutral (category 3) response is 0.20. As *rd* increases, the probability of agreement with the mission statement that the university's research curriculum has become more applied as a result of its involvement with organizations in a science park decreases. At *rd* = 50, the probability of agreement (category 4 or 5) to the statement that the curriculum has become more applied is over 95 percent. That probability falls to just about 87 percent at *rd* = 150, then to just about 70 percent at *rd* = 250, then to 45 percent at *rd* = 350 and so on. The point is that university R&D activity is an instrument that the university can use to control the impact that its involvement with its science park has on its curricular mission. As well, university R&D activity is an instrument useful in predicting, in a benchmarking sense, what impact to expect from its science park involvement. Interpreted slightly differently, the research culture of the university—and we suggest that the "strength" of that culture may be related to the intensity of the university's R&D activity—that also confers an academic reputation on the university, offsets outside (e.g., through science park relationships) influences that push the academic curriculum away from basic research toward applied research.

Second, consider a university planning a science park. Again, using the estimated coefficients in Table 4, we set selected variables as noted in Table 7 and then iterated over alternative values of *mileage* from 0, an on-campus science park, to 30 miles in 5-miles increments. As mileage increases, the probability of agreement with the mission statement that the university's research curriculum has become more applied as a result of its involvement with organizations in a science park decreases. Beyond 5 miles, the probability of strongly disagreeing that the university's research curriculum has become more applied rapidly approaches 100 percent. Obviously, proximity does matter. When planning an on-campus science park, *mileage* = 0, provosts should expect over time a significant (i.e., probability of agreement—as measured herein in terms of a response of 4 or 5—of nearly 80 percent) applied influence in the research curriculum from that relationship. *Ceteris paribus*, the probability of such an influence decreases rapidly when the cluster of industrial firms is off campus.

Certainly, much more needs to be learned about science parks, in general, and their influence on university activity, in particular. This exploratory paper is only a first step in the new learning about science parks and their effects on the academic missions of universities.

Figure 1



Science Parks in the United States from 1951-1998
Number of Science Parks
16
14
12
10
8
6
4
2
0
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
Year

Table 1
Sample of U.S. Universities (n=88)

Auburn U	SUNY Buffalo	NYU
U of Alabama at Birmingham	SUNY Stony Brook	U of Rochester
U of Arizona	North Carolina State	Yeshiva U
UC-Berkeley	U of North Carolina	Duke
UC-Davis	Ohio State	Case Western
UC-Irvine	U of Cincinnati	Carnegie Mellon
UCLA	U of Oklahoma	U of Pennsylvania
UC-San Diego	Oregon State	Vanderbilt
UC-Santa Barbara	Penn State	
Colorado State	U of Pittsburgh	
U of Colorado	Clemson U	
U of Connecticut	U of Tennessee	
Florida State	Texas A&M	
U of Florida	U of Texas-Austin	
U of South Florida	U of Utah	
Georgia Tech	Utah State	
U of Georgia	U of Virginia	
U of Hawaii	Virginia Tech	
U of Illinois, Chicago	U of Washington	
U of Illinois, Urbana-Champaign	Washington State	
Indiana U	U of Wisconsin	
Purdue U	Cal Tech	
Iowa State	Stanford	
U of Iowa	U of Southern California	
U of Kansas	Yale	
U of Kentucky	Georgetown	
LSU	U of Miami	
U of Maryland, Baltimore County	Emory U	
U of Maryland, College Park	Northwestern	
U of Massachusetts	U of Chicago	
Michigan State	Tulane	
U of Michigan	Johns Hopkins	
Wayne State	Boston U	
U of Minnesota	Harvard	
Mississippi State	MIT	
U of Missouri	Tufts	
U of Nebraska	Washington U	
Rutgers	Princeton	
New Mexico State	Columbia	
U of New Mexico	Cornell	

Table 2
Percent Distribution of Responses by Provosts to Mission Statements (n=29)

Mission Statement	Response Scale (1 = "strongly disagree" and 5 = "strongly agree")				
"As a result of my university's involvement with organizations in a science park, the …… "	1	2	3	4	5
overall research output, measured in terms of publications, by faculty has increased.	28%	7%	21%	21%	24%
overall research output, measured in terms of patents, by faculty has increased.	24%	10%	21%	24%	21%
overall extramural research funding by faculty has increased.	21%	10%	28%	17%	24%
research curriculum has become more applied.	24%	10%	31%	7%	28%
placement of doctoral graduates has improved.	24%	14%	28%	28%	7%
ability of the university to hire preeminent scholars has improved.	24%	28%	21%	17%	10%

Notes: The rows may not add to 100% due to rounding.

Table 3
Selected Mean Values, by Sample of Universities

University Characteristics	Population Sample (n=88)	Responding Sample (n=29)
park on campus (*parkoncampus*)	54.55%	65.52%
total academic R&D (*rd*)	$198.41M	$207.07M
% of total academic R&D from industry (*indrd*)	13.57	15.00%
% public universities (*pubpriv*)	69.32%	79.31%

Table 4
Ordered Probit Estimates of Agreement with Mission Statements

Variable	Mission Statement Coefficient (s.e.)					
	Publications	Patents	Extramural Research Funding	Applied Research Curriculum	Placement of Doctoral Graduates	Hiring of Preeminent Scholars
formal	**3.567 (1.105)*** **	**2.377 (0.905)*** **	**1.516 (0.728)** **	1.399 (1.067)	0.770 (0.650)	**1.950 (0.745)*** **
mileage	0.021 (0.029)	-0.048 (0.039)	0.038 (0.026)	**-0.730 (0.257)*** **	**-0.052 (0.031)* **	-0.0014 (0.026)
rd	-0.0005 (0.0041)	**0.0090 (0.0051)* **	**-0.0065 (0.0035)* **	-0.0064 (0.0052)	-0.0033 (0.0034)	**-0.0055 (0.0033)* **
dIT	**-2.199 (0.750)*** **	-0.755 (0.613)	**-1.10 (0.558)** **	**-1.098 (0.710)#**	-0.395 (0.523)	-0.448 (0.524)
dbiotech	-0.303 (0.596)	0.457 (0.701)	0.654 (0.537)	-0.119 (0.735)	0.645 (0.525)	-0.716 (0.534)
perinresrch	**0.176 (0.106)* **	-0.068 (0.092)	0.072 (0.090)	-0.013 (0.093)	-0.043 (0.083)	-0.045 (0.084)
agepark	0.016 (0.022)	**0.035 (0.023)#**	-0.013 (0.019)	**0.085 (0.033)** **	0.026 (0.019)	**0.044 (0.020)** **
prob8829	**7.081 (3.608)** **	**7.335 (3.585)** **	**7.330 (2.982)** **	-5.752 (4.659)	0.890 (2.642)	1.638 (2.770)
Number of Observations	26	26	26	26	26	26
Log Likelihood	-19.03	-20.35	-28.69	-17.00	-31.33	-30.69
Pseudo-R^2	0.510	0.476	0.299	0.564	0.197	0.241
Chi-squared (df)	39.61(8)***	36.98 (8)***	24.51(8)***	44.05 (8)***	15.39 (8)*	19.49 (8)**
cut1	2.95 (1.82)	4.20 (2.07)	1.04 (1.41)	-6.20 (2.67)	-0.69 (1.33)	-0.23 (1.34)
cut2	3.29 (1.85)	4.65 (2.08)	1.86 (1.44)	-3.75 (2.20)	-0.12 (1.31)	1.29 (1.38)
cut3	5.41 (2.15)	6.46 (2.27)	3.04 (1.50)	-1.21 (1.75)	0.94 (1.36)	2.02 (1.45)
cut4	7.26 (2.35)	8.07 (2.43)	3.88 (1.54)	-0.79 (1.74)	2.28 (1.42)	2.96 (1.49)
Mean *formal* (n=29)	0.655					
Mean *mileage* (n=29)	5.741					
Mean *rd* (n=29)	$207.07					
Mean *dIT* (n=29)	0.345					
Mean *dbiotech* (n=29)	0.414					
Mean *perinresrch* (n=28)	3.750					
Mean *agepark* (n=27)	19.185					
Mean *prob8829* (n=29)	0.363					

Notes: Significance levels denoted by #(15 percent), *(10 percent), **(5 percent), ***(1 percent).
From the sample of 29 responding universities, 2 listed science parks for which we were unable to determine the year in which the park began, thus we were unable to calculate the variable *agepark,* defined as (2000-year started). Also, a third university did not report a value for *perinresrch*.

Table 5
Parsimonious Ordered Probit Estimates of Agreement with Mission Statements

Variable	Mission Statement Coefficient (s.e.)					
	Publications	Patents	Extramural Research Funding	Applied Research Curriculum	Placement of Doctoral Graduates	Hiring of Preeminent Scholars
formal	**3.312** **(0.916)*****	**2.568** **(0.789)*****	**0.843** **(0.521)#**	1.358 (0.977)	**1.098** **(0.574)***	**1.920** **(0.679)*****
mileage		-0.035 (0.035)		**-0.739** **(0.245)*****	-0.033 (0.024)	
rd		**0.012** **(0.0048)****	**-0.0048** **(0.0028)***	-0.0058 (0.0048)		**-0.0051** **(0.0032)#**
dIT	**-2.335** **(0.694)*****		**-1.097** **(0.470)****	**-0.994** **(0.657)#**		
dbiotech						**-0.798** **(0.484)***
perinresrch	**0.159** **(0.092)***					
agepark		**0.030** **(0.021)#**		**0.0883** **(0.0335)*****	0.024 (0.017)	**0.045** **(0.019)****
prob8829	**5.768** **(3.089)***	**6.673** **(3.328)****	**4.023** **(2.516)#**	-6.129 (4.684)	0.131 (2.446)	1.705 (2.539)
Number of observations	28	27	29	27	27	27
Log Likelihood	-19.99	-24.21	-36.90	-17.71	-34.59	-32.46
Pseudo-R^2	0.519	0.420	0.186	0.559	0.157	0.231
Chi-squared (df)	43.11(4)***	35.05 (5)***	16.81 (4)***	44.90 (6)***	12.92 (4)**	19.50 (5)***
cut1	2.16 (1.04)	5.33 (1.88)	-0.53 (1.04)	-6.02 (2.45)	0.03 (1.04)	0.19 (1.01)
cut2	2.47 (1.08)	5.99 (1.91)	0.08 (1.04)	-3.63 (2.10)	0.68 (1.03)	1.59 (1.09)
cut3	4.42 (1.40)	7.30 (2.05)	1.06 (1.07)	-0.97 (1.66)	1.62 (1.08)	2.46 (1.16)
cut4	6.20 (1.61)	8.77 (2.23)	1.62 (1.07)	-0.58 (1.65)	2.91 (1.15)	3.41 (1.19)

Notes: Significance levels denoted by #(15 percent), *(10 percent), **(5 percent), ***(1 percent).

Table 6
Simulated Probabilities of the Impact of R&D on the Mission Statement about Applied Research Curriculum

Values of *rd*	Response Scale (1 = "strongly disagree" and 5 = "strongly agree")				
	1	2	3	4	5
50	5.76e-12	7.27e-06	.0363226	.0486478	.9150224
75	1.72e-11	.0000148	.0509664	.0616222	.8873966
100	5.00e-11	.0000295	.0699605	.0761231	.8538868
125	1.42e-10	.0000574	.0939765	.0917068	.8142592
150	3.92e-10	.0001089	.1235747	.1077441	.7685723
175	1.06e-09	.0002017	.1591274	.1234503	.7172206
200	2.79e-09	.0003647	.2007432	.1379426	.6609495
225	7.17e-09	.0006438	.2482034	.1503184	.6008344
250	1.80e-08	.0011097	.3009194	.1597475	.5382233
275	4.39e-08	.0018680	.3579203	.1655633	.4746484
300	1.05e-07	.0030711	.4178740	.1673410	.4117138
325	2.44e-07	.0049322	.4791431	.1649486	.3509759
350	5.54e-07	.0077387	.5398691	.1585636	.2938281
375	1.23e-06	.0118649	.5980766	.1486505	.2414068
400	2.65e-06	.0177789	.6517856	.1359055	.1945273
425	5.59e-06	.0260425	.6991210	.1211756	.1536553
450	.0000115	.0372988	.7384090	.1053661	.1189146
475	.0000231	.0522458	.7682551	.0893498	.0901261
500	.0000453	.0715937	.7876014	.0738912	.0668684
525	.0000868	.0960055	.7957641	.0595933	.0485502

Settings: *formal* = 1, *mileage* = 0 (i.e., on campus park), *dIT* = 0 and *dbiotech* = 0, *perinresrch* = 3.75 (sample mean), *agepark* = 19.2 (sample mean), and *prob8829* = 0.36 (sample mean)

Table 7
Simulated Probabilities of the Impact of Mileage on the Mission Statement about Applied Research Curriculum

Values of *mileage*	Response Scale (1 = "strongly disagree" and 5 = "strongly agree")				
	1	2	3	4	5
0	3.64e-09	.0004286	.2134612	.1416590	.6444511
5	.0164489	.6080237	.3733949	.0016144	.0005182
10	.9354324	.0645313	.0000362	3.58e-11	2.08e-12
15	.9999999	1.18e-07	1.28e-14	0	0
20	1.0	0	0	0	0
25	1.0	0	0	0	0
30	1.0	0	0	0	0

Settings: *formal* = 1, *rd* = 207 (sample mean), *dIT* = 0 and *dbiotech* = 0, *perinresrch* = 3.75 (sample mean), *agepark* = 19.2 (sample mean), and *prob8829* = 0.36 (sample mean)

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Endnotes

[1] Much of this literature is reviewed in Hall, Link, and Scott (2000, forthcoming) and in the papers in Siegel, Thursby, Thursby, and Ziedonis (2001). Formal university participation in industrial research joint ventures has increased steadily since the mid-1980s (Link 1996), 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 desire even more partnership relationships with industry (Morgan 1998). Mowery and Teece (1996, p. 111) contend that such growth in strategic alliances in R&D is indicative of a "broad restructuring of the U.S. national R&D system."

[2] In 2002, the Association was renamed the Association of University Research Parks (AURP).

[3] The lack of a standard definition of a science park is not unique to the United States. As Monck et al. (1988, p. 62) point out: "There is no uniformly accepted definition of a Science Park [in Britain] and, to make matters worse, there are several terms used to describe broadly similar developments—such as 'Research Park,' 'Technology Park,' 'Business Park,' 'Innovation Centre,' etc." The United Kingdom Science Park Association (UKSPA, 1985, p. ii) defines a science park in terms of the following features: "A science park is a property-based initiative which: has formal operational links with a university or other higher education or research institution; is designed to encourage the formation and growth of knowledge-based businesses and other organizations normally resident on site; has a management function which is actively engaged in the transfer of technology and business skills to the organizations on site."

[4] Incubator facilities house pre-start-up companies. Often, when the science park is tied to a state university, the state underwrites the cost of operating the incubator facility as part of a regional economic development strategy.

[5] Year of establishment is only one metric for dating the age and subsequent growth of science parks in the United States. It, like other metrics, is less than perfect since the date of establishment of a park may not be the date at which the first organization established itself in the park. In the case of the Research Triangle Park of North Carolina, the first tenant committed to the Park in 1965 (Link 1995, 2002; Link and Scott 2002) six years after the Park was formally established.

[6] There have, however, been a number of important and carefully done historical studies of the formation and/or growth of science parks. Castells and Hall (1994) and Saxerian (1994) describe the Silicon Valley (California) and Route 128 (around Boston) phenomenon; Luger and Goldstein (1991), Link (1995, 2002), and Link and Scott (2002) detail the history of Research Triangle Park (North Carolina); Gibb (1985), Grayson (1993), Guy (1996a, 1996b), and Vedovello (1997) summarize aspects of the science park phenomenon in the United Kingdom; Gibb (1985) also chronicles the science park phenomenon in Germany, Italy, Netherlands, and selected Asian countries; and Chordà (1996) reports on French science parks, Phillimore (1999) on Australian science parks, and Bakouoros et al. (2002) on the development of Greek science parks.

[7] See, Monck et al. (1988); Sternberg (1990); Westhead and Storey (1994); Westhead and Cowling (1995); Westhead, Storey, and Cowling (1995); Westhead (1997); Westhead and Batstone (1998); Löfsten and Lindelöf (2002); and Siegel et al. (2002). Implicitly, policy makers assume that science parks do add value to firm performance, as well as to local community development, as evidenced by the recent National Research Council studies of the proposed Sandia Science Park and Ames Research Center

(Wessner 1999, 2001). As Massey et al. (1992, p. 56) point out, the "environmental focus" that others have taken has merit:

> At the core of the science-park phenomenon lies a view about how technologies are created. This view is that scientific activities are performed in academic laboratories [and Massey et al. assume that at the core of a science park is a university] isolated from other activities. The resulting discoveries and knowledge are potential inputs to technology. Science provides break-throughs from which new technological goods may spring. … The argument goes that universities have many brilliant people making new discoveries but that they lack the means or the will to reach out to the market. *Science parks constitute a channel by which academic science may be linked to commerce* [emphasis added]. Thus science parks are there to promote, not 'science,' but its application in technology.

[8] A concern prior to administering the survey was whether a provost (including the resources the provost could draw upon) could meaningfully provide such information. During the pretest phase of the study we specifically explored this issue and found in all cases that there was institutional knowledge about the university-science park relationship, even in cases where the provost was only recently appointed. Further, during the follow-up telephone interviews, each respondent was asked whether non-response to the electronic survey was in any way because of ambiguity in the survey or an inability to respond accurately to the survey statements. Also, we discussed with the provosts involved in the pretest stage the appropriateness of the six academic mission statements.

[9] Alternative econometric approaches to the general question of how a university's relationship with organizations in a science park affects the academic missions of the university were considered. One alternative to exploring inter-university differences in perceived effects of a science park on academic missions would have been to collect quantitative data on aspects of university activity (e.g., publications, patents, extramural funds, curriculum, student placements, and hiring) and estimate for each university a time series model, controlling for the date that the university began its relationship with the science park. Such a model as:

(2) $\textit{academic activity}_{\text{t=0 to t=n}} = \text{f}\,(\textit{science park interaction}_{\text{t=0 to t=n}})$

has the benefit of relying on objective data to quantify academic activity on the left. However, the error in equation may be correlated (causing biases in the estimates of the model's coefficients) with the errors in the observations of the independent variables—errors that may be severe because there is no systematic way to date when a university began to have relationship with a park. Parks evolve over time from a concept to a development project to an infrastructure housing research partners. Research Triangle Park is a case in point. Faculty from Duke University, University of North Carolina, and North Carolina State University (then State College) were involved with the Park before the Park became a park. That is, faculty were integrally involved in research relationships with companies as far back as the late-1950s, although the first tenant did not commit to the Park until 1965 and began research operations more than a year later. In other cases, there have been long standing relationships between the university and the park, but the park has yet to move from a land development corporation to one with research tenants. Or, we could have created a matched sample of universities with and without a science park relationship and compared the performance of each group of universities. Such a model as:

(3) $\textit{academic activity}_{\text{university A vs. university B}} = \text{f}\,(\textit{science park interaction}_{\text{university A vs. university B}})$

also has the advantage of objective data on the left, but there is not a meaningful (as opposed to systematic) way to create a matched sample of universities that do not have a science park relationship. Again, we expect correlation between the error in equation and the errors in the explanatory variables. There are two main reasons for those errors. One, the relationship between a university and park is an evolving one, as just discussed, and, even controlling for age of park, the sample of universities with park relationships would still have a degree of heterogeneity that could not be matched in the sample of universities without park relationships. And two, we would have had no way to hold constant in such an experiment other industry influences on the university that occurred as a result of research or other interactions outside of the geographic park setting. As compared with our approach, the alternative approaches represented by equations (2) and (3) have some advantages despite the potentially bias-inducing errors in variables difficulties we have identified. Just as clearly, however, our approach has its own advantages, and the perceptions of the universities' provosts about the effects of the science park affiliations on the universities' missions are important in themselves. Although the dependent variables in the versions of equation (1) that were estimated clearly reflect perceptions, we are convinced, as a result of our pretests, that provosts reported well-informed perceptions. And, given that the dependent variable reflects perceptions, ordered probit is the appropriate econometric technique. The alternative models noted above would also have contained judgmental information, but would have done so in a manner that would be likely to create an important error in variables problem. Although there are econometric approaches to dealing with the errors in variables problem, the errors introduced in the two alternative models would be central to the time series investigation and especially intractable.

[10] Following this question we asked: If YES, what is the name of the science park and what is the nature of your formal relationship (e.g., joint research with selected organizations, joint appointments of faculty at a research institute, own the land the park is on, lease buildings to research companies in the park, etc.)?

[11] Following this question we asked: If YES, what is the name of the science park and what is the nature of your informal relationship (e.g., joint research or faculty members who have consulting positions with selected businesses or a research institute; have an incidental, real estate relationship with the science park but no formal joint effort between the university and the tenants to develop the park in ways that integrate the tenants' activities with the university's research resources; etc.)?

[12] Data on mileage between a university and its named science park came from Internet information about the university or about the park.

[13] These data came from National Science Board (2000, p. A-315).

[14] In 27 of 29 parks we could identify the year the park was formed using information from the Internet and from AURRP (1998).

[15] The following probit estimates were used to calculate *prob8829*:

Probit Estimates of Probability of Selection into the Sample of 29 Respondents (n=88)
Resp29 = 1 if Provost Responded to the Survey and Provided Relevant Information

Variable	Coefficient (s.e.)	P>|z|
parkoncamp	0.403 (0.289)	0.162
indrd	0.011 (0.012)	0.361
pubpriv	0.427 (0.322)	0.184
Intercept	-1.127 (0.367)	0.002
Log Likelihood	-53.41	
Pseudo-R^2	0.043	
Chi-squared (df)	4.74 (3)	P > Chi-squared = 0.192
Mean *resp29* (n=88)	0.330	
Mean *parkoncamp* (n=88)	0.545	
Mean *parkoncamp* (n=29)	0.655	
Mean *indrd* (n=88)	13.568	
Mean *indrd* (n=29)	15.000	
Mean *pubpriv* (n=88)	0.693	
Mean *pubpriv* (n=29)	0.793	

Notes: P>|z| denotes the probability that the absolute value of the ratio of the estimated coefficient to its standard error would be greater, given the null hypothesis of a zero coefficient. The coefficients for *parkoncamp* and *pubpriv* are substantially larger than their standard errors, although they are not significantly different from zero by classical standards. The probabilities predicted by the model are important in explaining the provosts' responses to some of the mission statements.

[16] Alternatively, the hazard rate from the probability of response model can be used to control for systematic components in the error that are associated with selection into the sample. Results are similar using the hazard rate rather than the probability of selection.. We prefer to control for the possibility that something in the error is associated with the selection into the sample by using the probability of response directly. The specifications for our models are exploratory, and Maddala (1983, p. 269) points to evidence "that the normal selection-bias adjustment is quite sensitive to departures from normality." The use of the probability of response rather than the hazard rate has straightforward, intuitive meaning that is not dependent on an assumption of joint normally distributed disturbances for the response probit and the ordered probit models.

[17] Nelson (2001) is concerned that commercialization of university research may have a detrimental effect on its "public science." Stephan (2001) observes that university/industry research partnerships have a potential to have a detrimental affect on the university's basic research curriculum. This issue is discussed in more detail in Poyago-Theotoky, Beath, and Siegel (forthcoming).

[18] We did investigate the possibility of a nonlinear age of park effect, but that variable never entered at even a marginally significant level.