U.S. University Research Parks

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Abstract:

University research parks are important as a mechanism for the transfer of academic research findings, as a source of knowledge spillovers, and as a catalyst for national and regional economic growth. We develop a model to describe the growth, or productivity, of research parks, and we test this model using the newly constructed National Science Foundation database on university research parks. We find that parks closer to the university, operated by a private organization, and with a specific technology focus—information technology in particular—grow faster than the average of 8.4% per year.

Keywords: research park | science park | university research | technology transfer

Article:

Introduction

University research parks (URPs) are important as a mechanism for the transfer of academic research findings, as a source of knowledge spillovers, and as a catalyst for national and regional economic growth.[1] Despite these contributions, there are few managerial benchmarks to follow to ensure the growth and possible success of university research parks; and, more generally, the place of URPs in the U.S. innovation system is not well understood. In large part, this gap in understanding stems from the lack of well-defined constructs about what constitutes a university research park, the variety of goals of a research park, and the general lack of clear metrics for measuring their success.[2] This paper, using the newly constructed national database on university research parks, represents, in our opinion, an initial step in filling this void.

[1] This generalization follows from the rich economics literature on the impact of basic research, which is performed in universities for the large part, on the productivity growth of firms that use that research (Griliches 1986; Link 1981; Link and Siegel 2003; Mansfield 1980) and the economic development literature on the impact of research clusters on regional economic growth (Porter 2001; Swann et al. 1998).

[2] These points were recently emphasized at the National Science Foundation-sponsored science park indicators workshop, convened at the University of North Carolina at Greensboro in November 2002. Based on the findings from the workshop, the National Science Foundation set forth an initiative to develop a national database on university research parks. This database, constructed for the National Science Foundation by Link, forms the basis for the analysis presented herein.

In the following section, we posit a synthesized definition of a URP. Then, in section 'The growth of university research parks', we develop a model of park growth, where park growth is widely accepted as a measure of park productivity or success.[3] We test the model using the newly constructed National Science Foundation database on university research parks. Finally, in section 'Discussion of the findings', we conclude the paper with a discussion of the potential usefulness of our findings for university and research park administrators who are strategically involved in the development of parks, and with an initial discussion of university research parks as an element of our national innovation system.

A definition of a university research park

A number of definitions of a research or science park have been proffered by various institutions or associations. See the Appendix for such definitions. In this paper, we proffer the following succinct definition of a university research park:[4]

> *A university research park is a cluster of technology-based organizations that locate on or near a university campus in order to benefit from the university's knowledge base and ongoing research. The university not only transfers knowledge but expects to develop knowledge more effectively given the association with the tenants in the research park.*

Generally, if the park is on or adjacent to a university campus the university owns the park land and either oversees, or at least advises on, aspects of the activities that take place in the park as well as on the strategic direction of the park's growth.[5,6] When the park is located off campus, it is often the case that the park land is owned by a private venture—and sold or leased to tenants—but the university had contributed financial capital to its formation and/or intellectual capital to its operation; therefore, there are elements of an administrative relationship between the university and these research parks.[7]

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[3] Link and Link (2003), based on extensive interviews with URP directors, and Link and Scott (2003b), based on extensive interviews with university provosts, conclude that employee growth is the dominant metric that those associated with a university research park use to quantify its productivity or success over time. Emphasis on employment is intuitive, since most research parks are associated with a state university (discussed below), and a part of the motivation for the university to establish the park is regional economic growth. Technology transfer-related metrics (e.g., university start-ups or licensed technologies to park tenants) or student placements are important, but are rarely considered as productivity or success measures.

[4] This is the definition that will be used by the National Science Board in its forthcoming *Science and Engineering Indicators, 2006*.

[5] Such oversight may include tenant criteria for leasing space in the park (Link and Link 2003). Such criteria may specify particular technologies or state that the tenant must maintain an active research relationship with university departments and their students.

[6] Approximately 6% of existing parks are formally affiliated with more than one university (e.g., Duke University, North Carolina State University, and University of North Carolina have a formal relationship with Research Triangle Park.)

[7] The form of the relationship between the university and the research park can be very explicit, as in the case when the university owns the park land and buildings and leases space to criteria-specific tenants; or very implicit, as in the case when the privately owned park is juxtaposed to the university and the university owns and operates buildings on park land. Certainly, a physical relationship between the university and the park does not necessarily imply an administrative or strategic relationship. The inability to quantify all of the dimensions of the dynamics of such relationships is an issue suggesting cautious interpretation of the quantitative analysis below.

Universities are motivated to develop a research park on their own or in partnership by the possibility of financial gain associated with technology transfer, the opportunity to have faculty and students interact at the applied level with technology-based organizations, and by the responsibility of contributing to a regional-based economic development effort.[8,9] Research organizations are motivated to locate in a research park to gain access to faculty, students, and research equipment, and to foster research synergies.

Based on the definition above, the population of currently active URPs, as defined in the National Science Foundation database on university research parks, is shown in Fig. 1. Notable in the figure 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). Also notable in the figure is the increase in park formation that began in the late-1970s and accelerated in the early 1980s.[10]

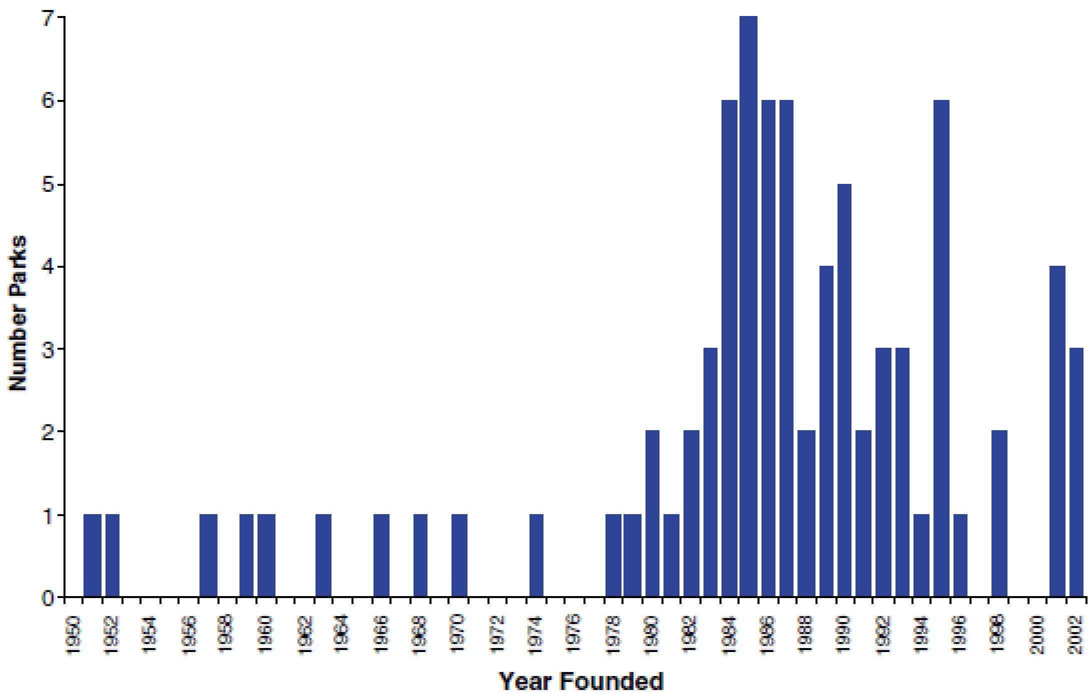

Fig. 1. Population of university research parks, by year founded (n = 81)

During the early and mid-1970s, real industrial R&D spending decreased. Based on National Science Foundation data reported in the National Science Board's (2002) *Science and*

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[8] In most cases, regional economic development is one justification of the creation of a university-related research park. Based on information from university websites and from surveys of park directors, in approximately 11% of the cases the research park's location was in either a distressed urban area or on an abandoned public-sector area (e.g., Yale University's Science Park is located in what had been an abandoned Winchester gun factory in New Haven).

[9] Just over 50% of university-related research parks were initially funded with public moneys. Of those, the public sector supported about 70% of the initial park cost.

[10] Danilov (1971) attributes the relatively long period from about 1960 to the early 1970s, during which the research park movement seemingly stalled, to a number of park efforts that failed as well as to the restraints on corporate R&D growth because of a lackluster economy.

Engineering Indicators, 2002, the real R&D performed in industry decreased in 1970 and 1971, and then again in 1974 and 1975.[11] It was not until 1977 that real R&D performed in industry was able to return to its 1969-pre-decline level, and relatedly, in 1978 park formations began to increase. It is reasonable to hypothesize that private sector demand for research park space increased during this R&D growth period because firms were looking for cooperative research partnerships to expand their research portfolios, as opposed to development portfolios.

The period of the relatively rapid increase in park formation corresponds to a period of significant public policy initiatives to encourage university-with-industry relationships, increases in industrial R&D spending, and the formation of cooperative research partnerships. The Bayh-Dole Act was passed in 1980, the R&E tax credit was enacted in 1981, and the National Cooperative Research Act was legislated in 1984.[12] All of these public initiatives fostered additional private sector R&D activity, which could have stimulated states and universities to establish potentially beneficial locations for that R&D to take place.

Not shown in the figure, but important for an overall understanding of the trend in the establishment of university research parks is the fact that there are an additional 27 parks—30% of the existing population—in the planning stage.[13] These parks are being structured by both leading research universities and universities that have traditionally had teaching as a primary mission. Our interpretation of this renewed growth in parks is influenced by discussions with park directors from both established parks and from planned parks. Increasingly, universities are adopting alternative strategies for the transfer of their own technologies, and success will increase the universities' revenues.

The growth of university research parks

The growth model

Based on the data underlying Fig. 1, we model the growth of URPs over time as:

$$y(t) = ae^{gt}e^{\varepsilon} \tag{1}$$

where *y(t)* is the research park's employment *t* years after it was established, *a* is the minimum efficient startup scale for a research park, *g* is the annual rate of growth of the park, and ε is a random error term.

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[11] R&D can be financed directly or indirectly from firm debt, equity, cash flow, and the federal government. See National Science Board (2002), Appendix Table 4.4.

[12] The University and Small Business Patent Procedure Act of 1980, known as the Bayh-Dole Act, reformed federal patent policy by providing increased incentives for the diffusion of federally funded innovation results. In particular, universities were permitted to obtain titles to innovations developed with government funds. The R&E tax credit of 1981 provided a tax incentive (originally 25% and today 20%) to firms that increased their R&D expenditures over those made in previous years. And, the National Cooperative Research Act of 1984 encouraged the formation of research joint ventures (RJVs) among U.S. firms—and universities were partners in many of those ventures. RJVs, if subjected to criminal or civil antitrust action, would be evaluated under a rule of reason, and if found to fail a rule of reason, they would be subjected to actual rather than treble damages.

[13] Only two of the 27 planned parks are at private universities.

The growth rate for a park is hypothesized to be a function of various explanatory variables, x_1 to x_k, as

$$(\partial y(t)/\partial t)/y(t) = g = b_0 + b_1x_1 + \cdots + b_kx_k \qquad (2)$$

From Eq. (1):

$$ln\, y(t) = \ln a + gt + \varepsilon \qquad (3)$$

Substituting Eq. (2) for g into Eq. (3):

$$ln\, y(t) = \ln a + b_0t + b_1x_1 + \cdots + b_kx_kt + \varepsilon \qquad (4)$$

Equation (4) is the growth model estimated in this paper.[14]

The definition of variables

The variables, x_1 to x_k, are motivated by previous empirical research and economic reasoning; the variables are described in Table 1 and discussed below.

Data used in the estimation of Eq. (4) came from a Number of sources. Published data from associations and park web sites were used initially to identify the population of university research parks. However, neither of these sources was complete, and, in most cases, not current. The information was then supplemented through survey interviews (mail and telephone) with park directors and university research administrators or designates.[15] Whenever contradictory information was discovered, it was assumed that the interview information was correct.

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[14] Our approach yields a sensible, estimable growth rate. An alternative to the growth model in Eq. (1) is a production function representation of park output. If employment, y, is interpreted as park output, and if inputs include park age, t, and a vector of other institutional variables, $\mathbf{X}$, then:

$$yt = f\,(t, \boldsymbol{X})$$

If this functional form is Cobb-Douglas:

$$y_t = t^{\alpha} X_1^{\beta_1} \cdots X_k^{\beta_1}$$

then after taking logarithms:

$$\ln y_t = \alpha \ln t + \beta_1 \ln X_1 + \cdots \beta_k \ln X_k$$

While this production function could be estimated, it does not yield a sensible estimate of park growth because of the constraint that the functional form imposes on employment as a function of time. The functional form posits an elasticity (α) of employment with respect to time. The use here of elasticity with respect to time is not sensible, because the percentage change in time is not a meaningful concept in this context. The growth rate (α/t in the production function model of this footnote) in employment would therefore be constrained to fall as time increases. One could use the model to derive growth rates for each different age (the variable t) for a park. If one had a sample for which all parks were the same age, t would be dropped from the model and the estimated intercept term would be the estimate of $\alpha \ln t$, from which an estimate of the parameter α could be derived. Alternatively, the model could include the variable $\ln t$, but be fitted without an intercept, with the coefficient estimated for $\ln t$ being the estimate of α. For the usual samples with parks of many different ages (many different values for t), dummy variables could theoretically be used to estimate a different value of α for the parks of each different age. However, degrees of freedom will typically not be sufficient to allow the estimation, so as a practical matter the approach is not feasible.

[15] Link and Link (2003) and Link and Scott (2003b) report findings from a portion of this field research.

Table 1. Description of Variables (n = 81)

Name	Description	Mean	Range
y_t	Employment level in either 1997 or 2002, depending on latest data availability	2805.57	1–45,000
t	Age of the park measured by the number of years since the park was founded; this variable is constructed to correspond to y_t	15.05	0–51
mile	Miles from park to university; 4 of 81 parks are associated with more than one university and in those cases mileage is to the nearest university	4.56	0–35
oper	=1 if the park is operated by the university; 0 if park operated by a foundation or private contractor	0.33	0–1
nouniv	Number of universities associated with the park	1.10	1–4
techit	=1 if IT is the advertized dominant technology of park tenants; 0 otherwise	0.17	0–1
techbio	=1 if bioscience is the advertized dominant technology of park tenants; 0 otherwise	0.20	0–1
regw	=1 if university is in West; 0 otherwise	0.22	0–1
regne	=1 if university is in Northeast; 0 otherwise	0.21	0–1
regmw	=1 if university is in Midwest; 0 otherwise	0.23	0–1
incub	=1 if incubator located in the park; 0 otherwise	0.56	0–1
statepr	=1 if university is state; 0 if university private	0.83	0–1

Note: In the context of our growth model, each of the above variables is weighted by the age, t, of the park

The growth model above is formulated in terms of time, t, which is the age of the park. Data on park employment was generally available for 2 years, 1997 and 2002. In most instances, t is the number of years since the park was founded to year 2002.[16] In those cases when only 1997 data were available, t was calculated as the number of years since the park was founded to year 1997.[17] The variable *mile* quantifies the geographical relationship between the university and the park. Twenty-eight parks from the population of 81 university research parks (see Fig. 1) are located on the university campus. Another eight are juxtaposed to the university campus (within 1 mile of the campus). Adams and Jaffe (1996) suggest that communication costs related to collaborative R&D activity increase with distance. Wallsten (2001) shows geographic proximity to other successful innovating firms, as evidenced by firms receiving a Small Business Innovation Research (SBIR) award, is associated with a firm's own success. These papers, as well as the works of Feldman (1999), Feldman and Lichtenberg (2002), and Adams (2002) motivate the inclusion of the mileage variable. We hypothesize that the closer a park is to the university the greater the knowledge flows among park tenants and the university and thus the more attractive the park for new tenants and employment growth. In the context of our growth model, mileage, represented in the interaction term $mile*t$, should enter negatively.

[16] Data are sporadically available on the year that the first tenant entered the park. We know from numerous interviews and park histories, that there is a long and variable lag between a park's founding and its first tenant. For example, the first tenant located in Research Triangle Park, NC in 1965, 6 years after the park was founded (Link 1995; Link and Scott 2003a).

[17] As shown in Fig. 1, three parks were founded in 2002; however, employment in those parks in that year was 0. Of the four parks founded in 2001, employment in one was 0 in 2002. And, one park founded in 1992 had 0 employees in 1997 and no information could be obtained for employment in 2002. For those five cases, employment was set at 1 to account for the known fact that there was a park director in each. This is seen in Table 1 in the range of values for y_t, and in the text's discussion of the various samples used in Table 2.

Twenty-seven of the 81 parks are operated by the university, and the remaining parks are operated by a non-university related foundation or a private contractor. Bozeman and Crow (1991); Bozeman (2000); Hall et al. (2001, 2003); and Siegel et al. (1999, 2003) suggest that the red tape associated with a bureaucracy, a state university in particular, is often an insurmountable barrier. As such, private sector firms could be deterred from entering the park for lack of willingness, or an ability, to cope. We hypothesize that parks operated by the university will experience slower growth because of, among other things, organizational bottlenecks created in the park by the university and a general lack of expertise on the part of the university in economic development activities. Alternatively, university operations may be associated with more challenging technology transfer and hence slower overall growth of the park. The alternative interpretation here is controlled to some extent by the variable *incub* as discussed below. With either interpretation, in the context of our growth model, the variable indicating whether or not the park is operated by a university, in the interaction term *oper∗t*, should enter negatively.

Four of the 81 parks are associated with more than one university. If the number of universities proxies economies of scale and scope in gaining access to faculty, students, and research equipment, and in fostering research synergies, then *nouniv*t* should enter positively in our model.

It is not uncommon for newly founded parks to have a technology focus. This, according to park directors, is a competitive strategy to lure new companies away from more established infrastructures.[18] Among the population of parks, 30 are either focused on building a cluster of information technology (*it*) or bioscience companies (*bio*). We offer no hypothesis about how such a technology-focused strategy has affected the productivity of parks. Thus, the interaction terms *techi t∗t* and *techbio∗t* are viewed as control variables.

Also held constant are regional dummies interacted with time, *t*: *regw*t, regne*t, regmw*t*;[19] if there is an incubator facility located in the park, *incub*t*;[20] and if the university is state or private, *statepr*t*.[21] These variables are included in our model to control for alternative park and university characteristics. We offer no set hypotheses about the direction or magnitude of their impact on park growth, although we have noted the possibilities that (1) state universities may be

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[18] The majority of the 27 planned parks tentatively state a technology focus.

[19] Following the U.S. Bureau of the Census classification, the Northeast includes: Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, Pennsylvania, and New Jersey. The South, captured statistically in the intercept term, includes: Delaware, Maryland, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Alabama, Mississippi, Florida, Louisiana, Arkansas, Oklahoma, Texas, and the District of Columbia. The Midwest includes: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio. And the West includes: Alaska, Washington, Oregon, California, Montana, Idaho, Nevada, Wyoming, Utah, Arizona, Colorado, New Mexico, and Hawaii.

[20] Nekar and Shane (2003) show that newly founded firms are more likely to survive in the presence of an incubator, but to our knowledge there is no literature on how incubators are associated with the growth of clusters of organizations. We do know, however, that incubators are established to assist newly established firms and university spin-offs, both of which are small in size and are likely to grow very slowly while within the research park. As discussed in section 'The empiral results', success and rapid growth for companies initially assisted by incubators may come after they leave the park.

[21] State universities receive state funding and may be more accountable for research activities and technology transfer activities than private universities.

more accountable for research and technology transfer (with positive effects on productivity) and — in part for that reason—may have more bureaucratic red tape (with negative effects on productivity) and (2) incubators are associated with newly established firms of types that are likely to demonstrate slow *within-park* growth. However, we do note that, *a priori*, we expect *different* opportunities and resources for parks in different regions, parks with incubator facilities as contrasted to those without them, and parks affiliated with state universities rather than private ones. Conventional two-tailed tests for the significance of the coefficients for the control variables will reveal if the differences are associated with different rates of growth for the parks.

The empirical results

The regression results associated with alternative specifications of Eq. (4) are in Table 2. Results are reported for the population of 81 parks and for two sub-samples. The first sub-sample deletes the three parks founded in 2002 because insufficient time has passed for them to attract tenants. The second sub-sample also deletes the one park founded in 2001 and the one park founded in 1992 for which no employees have yet located. As discussed above and as noted in Table 1, y_t for these five parks is set at 1. The essential results—as seen in columns (1) through (3)—are robust across the different samples. In the discussion to follow we use the results in column (3).

Column (3) shows the annual rate of growth for university research parks located on campus (*mile* = 0) and with one associated university (*nouniv* = 1) to be 0.1025 + 0.0186 or 12.1% for parks in the South when none of the qualitative variables in the model are 'turned on.' The annual rate of growth for parks in the Northeast, Midwest, or West does not differ significantly, *ceteris paribus*.

The coefficient on each of the variables other than time, t, each variable being interacted with t, gives the variable's effect on the annual growth rate. The growth rate of research parks does vary by park and technology characteristics. The coefficient on the driving distance (in miles) from the university to the park is negative, as hypothesized. For smaller mileage, the annual growth rate decreases by about 8% for every 10 miles between the university and the park. This effect diminishes as mileage increases.[22]

The number of universities formally affiliated with the park has a positive effect on growth. Going from 1 university to 2 universities increases growth by nearly 2% per year.

One-third of all parks are operated by the university, and the rest of the parks are operated by a private sector organization. As hypothesized, either the park operational skills of the university are less effective, at least in terms of park growth, or universities operate parks that on the whole undertake more commercially challenging technology transfer. University operated research parks grow on average about 5% per year slower than parks operated by a private sector organization.

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[22] The strong negative effect for low mileage gradually diminishes until miles = 0.0078/0.0004 = 19.5 miles. The functional form allows capturing the diminishing of the negative effect, and the eventual upturn in the effect over high mileage is probably not of interest. The range for *mile* is 0–35 miles, but only three parks have *mile* > 19.5. The median value for *mile* is 2.0, and 44% of the 81 parks are closer than 2 miles from their university.

Table 2. Regression results for Eq. (4) dependent variable: ln y_t

Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
t	0.1309***	0.1117***	0.1025***	0.1356***	0.1157***	0.1068***
	(0.0341)	(0.0302)	(0.0285)	(0.0336)	(0.0298)	(0.0282)
*mile*t*	–0.0100***	–0.0088***	–0.0078***	–0.0088***	–0.0079***	–0.0067***
	(0.0030)	(0.0027)	(0.0025)	(0.0029)	(0.0028)	(0.0025)
$mile^2*t$	0.0003**	0.0002**	0.0002**	0.0002**	0.0002**	0.0002*
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
*nouniv*t*	0.0101	0.0153*	0.0186**	0.0087	0.0141*	0.0174**
	(0.0097)	(0.0085)	(0.0076)	(0.0096)	(0.0084)	(0.0075)
*oper*t*	–0.0538**	–0.0580***	–0.0534***	–0.0864**	–0.0851***	–0.0822***
	(0.0218)	(0.0206)	(0.0192)	(0.0348)	(0.0318)	(0.0307)
*regw*t*	–0.0142	–0.0145	–0.0199	–0.0194	–0.0188	–0.0246
	(0.0266)	(0.0253)	(0.0248)	(0.0275)	(0.0261)	(0.0254)
*regne*t*	0.0280	0.0157	0.0032	0.0288	0.0164	0.0039
	(0.0278)	(0.0265)	(0.0247)	(0.0278)	(0.0267)	(0.0250)
*regmw*t*	–0.0045	–0.0083	–0.0131	–0.0071	–0.0104	–0.0154
	(0.0270)	(0.0213)	(0.0178)	(0.0261)	(0.0207)	(0.0172)
*techbio*t*	0.0266	0.0227	0.0167	0.0274	0.0234	0.0174
	(0.0208)	(0.0208)	(0.0214)	(0.0209)	(0.0205)	(0.0210)
*techit*t*	0.0429**	0.0457**	0.0436**	0.0492**	0.0509**	0.0492**
	(0.0202)	(0.0181)	(0.0170)	(0.0219)	(0.0198)	(0.0188)
*incub*t*	–0.0288*	–0.0259*	–0.0268*	–0.0218	–0.0202	–0.0207
	(0.0160)	(0.0146)	(0.0141)	(0.0170)	(0.0158)	(0.0155)
*statepr*t*	0.0511*	0.0304	0.0155	0.0378	0.0195	0.0038
	(0.0265)	(0.0238)	(0.0213)	(0.0285)	(0.0261)	(0.0232)
(*oper*statepr*)**t*				0.0511	0.0424	0.0453
				(0.0459)	(0.0433)	(0.0412)
contstant	4.2093***	4.8398***	5.2847***	4.185***	4.8167***	5.2603***
	(0.5096)	(0.4165)	(0.2717)	(0.5092)	(0.4153)	(0.2675)
R^2	0.51	0.51	0.56	0.51	0.51	0.57
F value	12.38***	11.15***	15.23***	10.48***	9.96***	13.57***
n	81	78	76	81	78	76

Note: Robust standard errors in parentheses. Significance levels denoted by∗ (10%), ∗∗ (5%), ∗∗∗ (1%). Coefficients and standard errors in column (3) are discussed within the text

Those parks that specialize in attracting information technology companies grow faster than other parks, either bioscience specialty parks or parks with heterogeneous technologies represented by the tenant mix, by slightly more than 4% per year.

Just over one-half of all parks have incubators within the park.[23] The negative coefficient on that variable shows that research parks with incubator facilities grow nearly 3% slower per year than parks without. This finding could mean, from an institutional perspective based on our discussions with park directors and university provosts, that incubator facilities assist with the growth of small companies, and then those small companies leave the park and rarely ever develop research synergies with other park tenants.

Finally, the ownership of the university — private university or public state university — has no statistical effect on park growth. Further, we investigated whether university ownership affects the efficiency with which state university operated parks grow. As the results in columns (4)–(6) show, university ownership is not statistically important in our model.

Using Eq. (2) from section 'The Growth of University Research Parks' and the estimates from column (3) of Table 2, the predicted growth rate for a park is:

$$\begin{aligned}\hat{g} = 0.1025 &- 0.0078(mile) + 0.0002(mile^2) \\ &+ 0.0186(nouniv) - 0.0534(oper) - 0.0199(regw) \\ &+ 0.0032(regne) - 0.0131(regmw) + 0.0167(techbio) \\ &+ 0.0436(techit) - 0.0268(incub) + 0.0155(statepr)\end{aligned} \quad (5)$$

The average value of $\hat{g}$ in the sample of 76 parks used in the model of column (3) is 0.0840 or 8.40%.[24]

Discussion of the findings

As the first systematic investigation of U.S. university research parks, our level of inquiry provides some new and interesting findings about the growth or productivity of research parks in the United States, but also it has several limitations, which we hope that researchers will address in the future. Before discussing the limitations of our study, we offer some additional insights into the direct usefulness of our findings.

Those involved in the 81 existing research parks as well as those associated with the planning and implementation of the 27 additional parks currently in the planning stage could use our statistical findings for benchmarking themselves against the population as a whole. Our findings

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[23] Unfortunately, we do not have data on the age of the incubator facility or its size.

[24] Equation (5) is our prediction model. One might reasonably expect that some of the right-hand-side variables, in particular whether *(oper* = 1*)* or not *(oper* = 0*)* a university operates the park, may be associated with the number of miles, *mile*, between the university and the park. For that reason, especially given the large number of explanatory variables, multicollinearity might conceivably make the estimation of the model difficult. As it turns out, although *mile* and *oper* are negatively correlated, the correlation coefficient is just −0.11 and is not significant. The equation (5) follows from our theoretical growth model. We did not experiment, nor do we think that we should, with exploratory specifications. Collinearity is not a problem in this particular sample; the estimation is stable, with the variables' coefficients the partial derivatives well estimated with relatively small standard errors.

may also be useful for guiding university and park administrators in making strategic decisions about their park.

Many of the variables in our growth model are not discretionary — an off-campus park cannot easily relocate on campus, and a university cannot change its ownership affiliation from being private to being public. But there are strategic options at the discretion of administrators. The first is who operates the park — the university or a private organization; the second is if the park is technology focused — information technology or biosciences. For illustrative purposes, Table 3 shows the average annual growth rates predicted by our models, based on column (3) in Table 2, for alternative distances between the university and the park, and for each form of operational structure. This experiment, which is also illustrated in Fig. 2, is based on the following assumptions: the single university (*nouniv* = 1) is a state university (*statepr* = 1) in the Northeast (*regne* = 1); there is no incubator facility in the park (*incub* = 0); and the park has a focus on information technology (*techit* = 1). Clearly, those involved in developing park growth strategy can locate the distance between their university and park and see the predicted growth differences associated with who operates the park. The predicted average annual rate of growth decreases for both private and university operated parks as mileage increases, and the rate of growth is significantly less in the university operated park.

Table 3. Predicted annual growth rates, by mileage and operational structure (in percentages)

Miles	$\hat{g}$ **Park Operated by Private Organization**	$\hat{g}$ **Park Operated by University**
0	18.34	13.00
1	17.58	12.24
2	16.86	11.52
3	16.18	10.84
4	15.54	10.20
5	14.94	9.60
6	14.38	9.04
7	13.86	8.52
8	13.38	8.04
9	12.94	7.60
10	12.54	7.20

Note: The predicted average annual growth rates come from the regression coefficients in column (3) of Table 2 given: *nouniv* = 1*, statepr* = 1*, regne* = 1*, incub* = 0*, techbio* = 0, and *techi t* = 1

These predictions, in particular, and the analysis presented in this paper, in general, must be interpreted cautiously. First, our analysis is subject to data limitations. For example, we were able to control for whether or not a university operates the park, but we could not control for the experience of those who operate the park. An experienced university management staff may well outperform, in terms of park growth, an inexperienced private organization's management staff. Further, we have not controlled for the age or expertise of the university's technology transfer office/officer, nor have we controlled for the research expertise of faculty. Also, given the alternative interpretation above of *oper*'s negative effect on growth, the results may reflect more commercially challenging technology transfer for university operated parks. Second, and this point relates to data limitations, our analysis is based on a rather simple growth model. Certainly, more insights about the growth of research parks could be gleaned when the growth process is modeled more completely by taking into account lags and simultaneous effects. But, even with these limitations, our analysis does begin to fill the conspicuous void about the growth of university research parks.

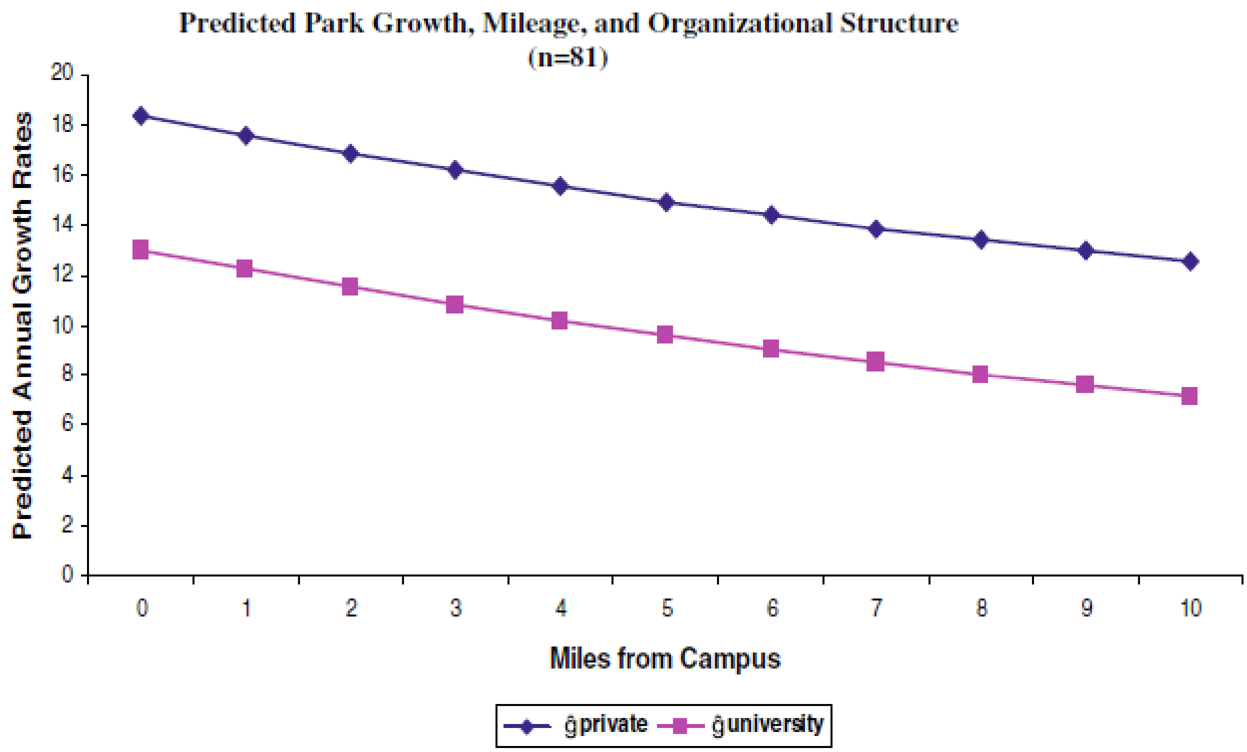

Fig. 2. Predicted park growth, mileage, and organizational structure (*n* = 81)

That said, we are aware that there are broader issues associated with university research parks than growth. Specifically, for a policy perspective, an overarching question relates to how university research parks fit within our national innovation system. Drawing on Cohen (2002),[25] a relevant question is whether university research parks increase R&D efficiently—both tenant R&D and university R&D — by enhancing information flows. If so, then it is not unreasonable to think of university research parks as an infrastructural component of our national innovation system.

Unfortunately, our analysis in this initial inquiry into university research parks is insufficient to answer the broader question about the efficiency of URPs.[26] However, we have offered a suggestive argument that park formations do increase R&D efficiency. In particular, the rise in park formation in the late 1970s when real industrial R&D was also increasing, and when the public sector introduced incentives to stimulate industrial and university innovation-related relationships, is consistent with firm and university strategies for purposive information sharing from which both parties benefit.[27] That, taken in conjunction with the fact that there are 27 new

[25] And Cohen's (2002) discussion builds on the work of Nelson (1993).

[26] This is because of the factors noted above and the fact that our dataset does not include information about research parks that may have failed and, if so, are no longer active or observable.

[27] These trends are not consistent with the findings that firm-with-firm (in separate geographical locations) RJVs are a countercyclical strategic response (Brod and Link 2001; Hagedoorn et al. 2000). The demand for park locations appears to increase during periods when industrial R&D activity is also increasing, and the supply of parks appears to increase during periods when firm R&D activity is growing and when incentives exist for technology transfers from universities. That observed increase in demand—R&D spending—reflects, in our opinion, a greater ability on the part of firms to take advantage of the juxtaposed synergies with other firms and the university that a park location affords.

university research parks in the planning stage at a time when technology transfer is burgeoning, suggests to us that as technology transfer activities at universities continue to increase there will be more and more universities that are eager to imitate the infrastructural successes of other universities with established parks. Still, the broad topic of university research parks is relatively new to the research domain of economics; and therefore, scholars in the future will certainly refine our analysis and begin to address the broader question about parks within our national innovation system.

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Appendix A

A number of definitions of a research park have been proffered in recent years. Beginning with the international definitions, the International Association of Science Parks (IASP) offers the following:[28]

A Science Park (or Technology Park, or Technopole or Research Park) is an organisation managed by specialised professionals, whose main aim is to increase the *wealth of its community* [emphasis added] by promoting the culture of innovation and the competitiveness of its associated businesses and knowledge-based institutions.

To enable these goals to be met, a Science Park stimulates and manages the flow of knowledge and technology amongst universities, R&D institutions, companies and markets; it facilitates the creation and growth of innovation-based companies through incubation and spin-off processes; and provides other value-added services together with high quality space and facilities.

The United Kingdom Science Park Association's (UKSPA) definition is more focused:[29]

> A science park is essentially a cluster of knowledge-based businesses, where support and advice are supplied to assist in the growth of the companies. In most instances, science parks are associated with a center of technology such as a university or research institute. In more detail, they are business support and technology transfer initiatives that:

- Encourage and support the start up, incubation and further *growth of innovative businesses with good growth potential* [emphasis added].
- Provide an environment where larger, frequently international businesses can develop scientific and close interactions with a particular center of technology for their mutual benefit.
- Usually have a formal and operational link with such a reservoir of technology.

[28] http://www.iaspworld.org/information/definitions.php
[29] http://www.ukspa.org.uk/htmlfiles/index1.htm

The United Nations Educational, Scientific and Cultural Organization (UNESCO) defines a science park as:[30]

> …an economic and technological development complex that aims to foster the development and application of high technology to industry. Research facilities, laboratories, business incubator, as well as training, business exchange and service facilities are located in the complex. It is formally linked (and usually physically close) to a centre of technological excellence, usually a university and/or research centre. Most science parks focus on information technology (including electronics and computers), telecommunication, biotechnology and new materials. The general characteristic of a science park is as follows:

- promote research and development by the *university in partnership with industry* [emphasis added], assisting in the growth of new ventures, and promoting economic development;
- facilitate the creation and growth of innovation-based companies through incubation and venturing; and
- stimulate and manage the flow of knowledge and technology amongst universities, R&D institutions, companies and markets;
- provide an environment where knowledge-based enterprises can develop close interactions with a particular centre of knowledge creation for their mutual benefit.

More specific to the United States, the Association of University Related Research (AURRP) parks defined a research park in the following terms:[31]

> 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

The AURRP recently changed its name to the Association of University Research Parks (AURP), and it set forth the following definition for a university research park.[32]

> A university research *park or technology incubator* [emphasis added] is defined by AURP as a property-based venture which has:

- Existing or planned land and buildings designed primarily for private and public research and development facilities, high technology and science based companies, and support services.

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[30] http://www.unesco.org/pao/s-parks/what.htm
[31] AURRP (1997).
[32] http://www.aurp.net/whatis/

- A contractual and/or formal ownership or operational relationship with one or more universities or other institutions of higher education, and science research.
- A role in promoting research and development by the university in partnership with industry, assisting in the growth of new ventures, and promoting economic development.
- A role in aiding the transfer of technology and business skills between the university and industry tenants.

The park or incubator may be a not-for-profit or for-profit entity owned wholly or partially by a university or a university related entity. Alternatively, the park or incubator may be owned by a non-university entity but have a contractual or other formal relationship with a university, including joint or cooperative ventures between a privately developed research park and a university.

A priori, each of the above definitions had limitations, and based on previous research none of these definitions is an accurate characterization of the U.S. phenomenon.[33] In particular, the IASP definition only emphasizes the regional economic growth aspects associated with park activity, but in some European countries that is the founding objective of many of the parks. The UKSPA definition appropriately emphasizes technology transfer from the university, but it is narrow in that it focuses on park company growth. Although the recognition of "mutual benefit" suggests a two-way flow of knowledge, the UNESCO definition like that of the UKSPA emphasizes a one-way knowledge flow from the university to the private sector. The AURP definition appropriately acknowledges that knowledge does flow in two directions between park tenants and the university. The AURP definition is appealing and formed the foundation for our working definition of a university research park.

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[33] See in particular Link (1995, 2002), Link and Link (2003), Link and Scott (2003a, 2003b). As one park director noted to us in a personal interview: "If you've seen *one* research park … you've seen *one* research park."

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