Available online at www.sciencedirect.com
SCIENCE DIRECT®

Research Policy 34 (2005) 1076–1090

research policy

www.elsevier.com/locate/econbase

Incubator firm failure or graduation? The role of university linkages

Frank T. Rothaermel [a,*], Marie Thursby [a,b]

[a] College of Management, Georgia Institute of Technology, Atlanta, GA 30332-0520, USA
[b] NBER, Cambridge, MA 02138, USA

Available online 11 July 2005

Abstract

One of the theoretically important factors for incubator firm performance is the strength of their linkages to the research university sponsoring the technology incubator. Herein, we focus on two types of university linkages to the sponsoring institution: a license obtained from the university and a link to university faculty, while controlling for incubator firm linkages to non-sponsoring research universities, among other factors. We propose that a university link to the sponsoring institution reduces the probability of new venture failure and, at the same time, retards timely graduation. Further, we suggest that these effects are more pronounced the stronger the university link. Due to the difficulty of obtaining fine-grained longitudinal data, the incubation literature is characterized by a dearth of studies focusing on incubator firm differential performance. We attempt to take a first step towards closing this gap by testing these hypotheses through following 79 start-up firms incubated in the Advanced Technology Development Center at the Georgia Institute of Technology over the 6-year period between 1998 and 2003. We find broad support for the hypotheses advanced.

JEL classification: L21; L25; L31; M13; O31; O32; R11

Keywords: Incubator firm performance differentials; University linkages; Commercialization of university technology; New venture creation

1. Introduction

According to the National Business Incubation Association, there are approximately 950 business incubators in North America, an increase of 160% over the last 5 years. Thirty-seven percent are classified as technology incubators and 25% are sponsored by academic institutions (Linder, 2003). The numbers suggest that technology incubators are a growing part of the institutional infrastructure for university industry technology transfer, and indeed practitioner publications tout the benefits of incubation for technology commercialization (Kalis, 2001; Tornatzky et al., 2002). There is, however, little systematic analysis of the role that technology incubators play in facilitating technology

* Corresponding author. Tel.: +1 404 385 5108; fax: +1 404 894 6030.
E-mail address: frank.rothaermel@mgt.gatech.edu (F.T. Rothaermel).

0048-7333/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.respol.2005.05.012

transfer and/or the success of high-technology start-ups. In this paper, we take a step toward filling this gap by examining the performance of 79 member companies of the Advanced Technology Development Center (ATDC) associated with the Georgia Institute of Technology (Georgia Tech) over the 6-year period between 1998 and 2003.

The ATDC's central function is to facilitate the growth of high-technology start-ups in Georgia. It offers access to laboratories and other research facilities at Georgia Tech, as well as business assistance, subsidized space, and connections to potential corporate partners, venture capitalists, and intellectual property guidance. Eligible companies must be based on technology that is proprietary in nature, protected by copyright or patents, and must have a research and development (R&D) focus. The technologies need not be based on Georgia Tech research, however, and while the incubator affords close proximity to university laboratories and faculty, companies need not avail themselves of these resources. In our sample, only 14% of the companies are start-ups based on licenses from Georgia Tech, while 61% have links with university faculty either informally (16%) or formally (22% with contractual agreements and 23% with faculty in senior management roles).

The data underlying this study come from two sources: a longitudinal repeat survey of ATDC companies and graduates starting in 1998 and ending in 2003, and data concerning Georgia Tech Licenses to start-ups. We examine incubator firm performance, as measured by failure, graduation or continued incubation, as a function of firm ties to the sponsoring university, controlling for other factors such as linkages to other, non-sponsoring research universities, firm patents, industry classification, firm size, total amount of funding obtained, and sources of funding. We find that strong ties to the sponsoring university, as measured by licensed technology or faculty as senior management reduce the likelihood of firm failure but also retard graduation from the incubator. Weak ties to the sponsoring university, such as informal interaction with faculty, do not appear to influence outright firm failure or timely graduation.

This article is organized as follows. Section 2 explores the role of university knowledge-based assets on incubator firm performance, Section 3 discusses methodology, Section 4 presents the results, while Section 5 concludes the paper with a discussion of the results, limitations, future research as well as managerial and policy implications.

2. University knowledge-based assets and incubator firm performance

One of the arguments for technology incubators associated with universities is the access to knowledge-based assets that are often needed for technology-based start-ups. Support for this argument can be found in an extensive empirical literature showing that knowledge spillovers tend to be localized (Jaffe et al., 1993). While some suggest that such spillovers are particularly beneficial for small firms (Acs et al., 1994; Audretsch and Feldman, 2004; Rothaermel, 2002), others find that larger firms tend to rely more heavily on publicly funded science (Cohen et al., 2002).

With few exceptions, this literature has been based on patent and publication citations or survey data, and has abstracted from whether firms are stand alone or incubator residents. Two exceptions are Siegel et al. (2003) and Rothaermel and Thursby (2005). Siegel et al. examine the effect of university science parks in the UK on firm research productivity. While they find that firms associated with science parks are more productive than those not so located, their data do not allow them to examine the nature of the connection between science park firms and the university. Rothaermel and Thursby (2005) explore the effect of university knowledge in general, and knowledge generated by Georgia Tech employees in particular, on incubator firm performance. They examine two types of mechanisms: (i) transfer by a license to a Georgia Tech invention and (ii) knowledge spillovers as measured by backward citations in incubator firm patents to university patents and publications. Applying a diverse set of performance indicators, they found little evidence of localized spillovers. Thus, the question of the means by which localized university knowledge-based assets benefit science park or incubator firms remains open.

Herein, we focus on the nature of different linkages to local university assets and the extent to which they affect the performance of firms within an associated incubator. We examine two measures of performance: the probability that a firm fails and the probability that a firm graduates within 3 years or less. Allowing a 3-

year time window for graduation is conservative since most start-ups graduate within 2 years from public and within 1 year from private incubators (Rosenwein, 2000). The university linkages that we examine include whether the underlying technology being developed is university intellectual property, represented by whether the technology is licensed from Georgia Tech, and a faculty link indicating the type of faculty involvement with the company.

2.1. Intellectual property (IP) link—Georgia Tech Licenses

Eleven of the firms in our sample (14%) are companies founded to develop Georgia Tech inventions and eight of these were founded by the inventor (58% of companies based on a GT License, 10% of total sample). In all cases, the firm has an exclusive license to use the invention, and all but three of the inventions have patents awarded or pending (79% of companies based on a GT License). Thus, one could argue that firms with a Georgia Tech License have strong property rights, putting them in a favorable position to appropriate the returns from the inventions licensed (Dechenaux et al., 2003). One could also make a quality signaling argument that, since the Office of Technology Licensing (OTL) granted an exclusive license and in eight cases filed for patents, these firms may well have a lower probability of failure than other firms in the incubator.

There are other factors, however, that would suggest the opposite, that Georgia Tech start-ups would have a higher probability of failure than other firms. In particular, university inventions are typically quite embryonic and high risk. Survey evidence from over 60 US universities and 113 businesses that licensed university inventions indicates that almost half of the inventions licensed are no more than a proof of concept when they are licensed and three quarters are no more than a lab scale prototype (Thursby et al., 2001; Thursby and Thursby, 2003). The business survey shows that university inventions have a high failure rate, with 42% of the respondents estimating that the inventions they licensed from universities had a higher failure rate than those they licensed from other businesses, and 11% indicating that university inventions had a lower failure rate (Thursby and Thursby, 2004).

The effect of the license link is further confounded by the fact that eight of the companies were founded by the inventor(s). Agency theory would suggest that founder involvement in a start-up should decrease the probability of failure (Fama, 1980). Further, founder involvement may also reflect “bold optimism” as suggested by the cognitive bias literature (Camerer and Lovallo, 1999), leading founders to remain committed to developing the invention longer than other management.

If the strong IP protection, quality signaling, and inventor involvement effects dominate, we would expect inventions licensed from the university to be negatively related to firm failure. If the stage of development effect is operative for this sample of inventions (stage of development is not available from our data) and dominates, the effect on failure rates would be positive.

With regard to the likelihood that a company will graduate in 3 years or less, however, one could argue that all four factors associated with a license from Georgia Tech would tend to slow graduation. With strong IP, a quality signal, an overly optimistic inventor, and an embryonic invention, one would expect the time to developing products and revenue, would be slow.

2.2. Faculty involvement

Although little is known about faculty involvement with incubator firms, there is a growing body of literature on technology licensing that emphasizes the role of faculty cooperation in successful commercialization of university inventions. In part because of the embryonic nature of most inventions licensed, there is a real need for inventors to cooperate with licensees in the further development required for practical use. Estimates of the extent of cooperation needed varies, with technology transfer personnel in universities indicating that 71% of the inventions licensed require faculty involvement for successful commercialisation, and licensing directors of businesses who license university inventions estimating that 40% of the inventions they license could not be commercialized without faculty cooperation (Thursby et al., 2001; Thursby and Thursby, 2004). Jensen and Thursby (2001) interpret this to indicate that inventor cooperation in development increases the probability that an invention is commercially successful.

It is important to note that this effect is independent of the founder involvement noted above, but is a function of inventor tacit knowledge that is often critical in development. Further, while this evidence pertains to inventor cooperation in developing their own inventions, it is natural to expect the same type of cooperation to be useful for companies developing any other high-tech products. Indeed, Zucker et al. (2002) find that many of the biotech firms in their sample reported star scientists on their management team. They find that firm success (as measured by patents, products in development, and products in the market) is consistently higher for firms with links to star university scientists (as measured by co-authorship of university and firm scientists). Interestingly, Audretsch and Stephan (1996) found that the degree to which biotechnology firms draw on local star scientists varies considerably across firms, from 19% at the low end to 80% at the high end. Their finding implies some variance with respect to the availability of local knowledge spillover emanating from star scientists.

Taken together, we expect faculty involvement with incubator firms to decrease the probability of failure. As discussed below, we have three measures of faculty involvement: faculty on the senior management team, contracts with faculty, and informal ties. While a number of studies find evidence of firm learning through informal ties and consulting contracts, we hypothesize that the effect of faculty involvement on firm success would be stronger when faculty are part of the senior management team (Agrawal and Henderson, 2002; Cohen et al., 1998; Thursby et al., 2004). We expect the strongest effect of faculty on the probability of failure to occur when the firm founder is the inventor for the reasons mentioned in the last section.

For the same reasons that we expect a license link to retard graduation, we also expect the faculty link to be negatively related to the probability of timely graduation. That is, technologies are more likely to need research faculty input the more embryonic they are. There is also evidence that university spinout companies may well grow faster when they rely on non-academic entrepreneurial talent (Franklin et al., 2001). In a different context, Darby and Zucker (2002) find that close association with star scientists speeds the progress of new biotech firms toward initial public offerings. Thus, one could argue that faculty involvement by stars could speed time to graduation. It is not clear, however, whether the effect of star scientist participation is not reputational, and therefore more related to VC funding or IPO valuation. Very few of the firms in this sample, if any, fit this profile, so we discount the importance of this effect for our sample.

3. Methodology

3.1. Research setting—Georgia Tech's ATDC

The Advanced Technology Development Center is a technology incubator sponsored by the Georgia Institute of Technology, a public research university, and is located adjacent to the Georgia Tech main campus in midtown Atlanta. The ATDC also receives legislative and financial appropriations from Georgia's Governor and the General Assembly of the state. The ATDC was founded in 1980 as one of the first technology incubators in the US, and has since generated a cumulative of 4100 jobs and US$ 352 million in total revenues as of December 31, 1998. The ATDC member firms had a total of US$ 12 million in annual revenues in 1998, US$ 19 million in 1999 and US$ 18 million in 2000. In the late 1990s, Georgia Tech's ATDC was voted as one of the top incubators in the US based on a survey of peer incubators conducted by Inc. magazine (Rosenwein, 2000). The ATDC focuses on incubating early stage companies (0–3 years), with the company's founding date generally coinciding with the firm's admission to membership into the incubator.

The ATDC managers actively solicit applications from new ventures, and admitted, during our study period, between 10 and 20% of their applicants after a fairly stringent, two-stage review process. As indicated above, it is not necessary that the technology underlying the new venture is related to Georgia Tech, yet, it must be proprietary in nature. During the last few years, the size of the full-time professional staff of the ATDC remained, despite turnover, fairly constant at 22 managers. These managers assist the commercialization efforts of the ATDC member firms.

3.2. Sample and data

The sample consists of the population of member firms in the Advanced Technology Development Center, a technology incubator, for the years 1998–2000.

A total of 79 firms were tenants of the ATDC during this 3-year time frame. The year 1998 marks the first year detailed data were collected for the firms in the incubator. We drew the sample based on the years 1998–2000 to be able to observe each start-up firm for a minimum of 4 years beginning with initial incubation in year t. We assessed the performance of the incubator firms at $t+y$, where $1 \leq y \leq 3$ years. For example, the performance of an incubator firm admitted in 1999 was evaluated in 2002 or earlier if a terminal event (i.e., failure or graduation) had occurred. Thus, the first possible year of evaluation for an incubator firm admitted in 1999 was 2000, while the latest possible year of evaluation was 2002. Applying a 3-year time window to assess incubator firm performance appears to be conservative given the fact that incubator tenants tend to graduate from public incubators within 2 years and from private incubators within 1 year (Rosenwein, 2000). In $t+y$, the start-up firm could fall into one of three categories: (1) failure, i.e., the firm ceased to exist due to bankruptcy or liquidation; (2) firm remains in the incubator; (3) successful graduation, i.e., the firm is a stand-alone going concern or was acquired. It is important to note, that while managers of the ATDC hope to graduate firms in a timely manner, this technology incubator does not have an explicit graduation policy. Each graduation decision is made on a case-by-case basis.

Data for the 79 firms were collected annually for the 6-year time period between 1998 and 2003 through a survey instrument that was administered to all firms in the sample in the spring of every year to collect data for the prior year. Accordingly, data collection began in the spring of 1999 and ended in the spring of 2004. This longitudinal, repeat survey approach allowed us to obtain an unequivocal performance outcome at $t+y$, where $1 \leq y \leq 3$ years, for all 79 firms in the sample. Thus, our results are not prone to a survivor bias, frequently observed in studies focusing on new venture creation and their early performance.

A second source of data was the Georgia Institute of Technology's Office of Technology Licensing. We obtained data on new ventures based on Georgia Tech Licenses including their founding date and industry. We augmented the collection of the quantitative data through semi-structured interviews with managers of the ATDC, the Institute's vice provost for economic development and technology ventures, the Institute's director of the technology licensing office, and the Institute's director of its VentureLab, a center founded to identify commercializable technologies within the Institute.

3.3. Measures

3.3.1. New venture performance

The performance of the newly formed technology venture at $t+y$ is the dependent variable of this study. We coded the performance of the new venture as a multinomial variable with three categories: failure, remaining in the incubator, and successful graduation. Remaining in the incubator serves as reference category.

3.3.2. Georgia Tech (GT) Link

A firm's link to the sponsoring research university is the key independent variable of this study. Here, we focused on the different strengths of a firm's link to Georgia Tech. First, we obtained a complete list of firms that were started based on a technology licensed from the sponsoring research university (*GT License*). Second, each firm was asked to indicate whether (1) it had an *informal contact* to one or more GT professors, (2) there existed a *contractual relationship* with one or more GT professors, (3) one or more GT professors were recruited as members of the firm's *senior management*, which includes GT professors as firm founders. When further decomposing a venture's GT senior management link, we explicitly assessed if the inventor of the technology was part of the firm's senior management (*GT Inventor in Senior Management*). In total, we employed seven different variables to track the different strengths and permutations of the start-up firm's linkages to the sponsoring research university in attempting to disentangle the role of university linkages in predicting successful graduation from the technology incubator.

The first variable (*GT License*) tracks whether the firm in the sample was founded to commercialize a technology licensed from the sponsoring university. The second variable (*GT Link—informal or contractual or senior management*) is an indicator variable taking on the value of 1 if the firm had engaged in any of the three possible linkages. The third variable (*GT Link—contractual or senior management*) tracks somewhat stronger linkages that go beyond mere informal involvements of GT professors, taking on the value of 1 if the firm had either a contractual arrangement with a GT professor and/or a GT professor was part of the firm's senior management. This approach allows us to test for the impact of successively stronger involvements by university professors in the new ventures.

The next three variables track university linkages exclusively for each category, and were each coded 1 if that specific *GT Link* existed (*informal only, contractual only, senior management only*). This enabled us to test for the specific effect of each mutually exclusive category of university linkage, while controlling for the other linkage categories. Finally, we triangulated the data obtained from Georgia Tech's Office of Technology Licensing with the data obtained from the annual survey to construct the variable *GT Inventor in Senior Management*, which is an indicator variable that takes on the value of 1 if the inventor of the technology was at the same time the founder or a senior management member of the ATDC firm that attempted to commercialize the new technology. This fine-grained variable aided us in understanding the effect of the type of senior management member (inventor versus non-inventor) on incubator firm performance.

3.4. Control variables

We employed a number of control variables that could affect a firm's probability to successfully graduate from a technology incubator.

3.4.1. Employees

If new ventures grow quickly, they tend to be on a steeper growth trajectory, and are thus, are more likely to graduate successfully. We controlled for firm size effects through the number of employees up to the year prior to which the outcome variable was assessed. Proxying firm size by the number of employees is particularly salient when studying new ventures because these firms frequently do not generate revenues and their assets tend to be intangible. Moreover, since newly created ventures tend to be quite small, we collected data not only on the number of full-time employees but also on the number of part-time employees. Each full-time employee was counted as one employee, while each part-time employee was counted as one half of a full-time employee.

3.4.2. Patents

We controlled for the intellectual property endowment of each firm through a cumulative count of the patents filed and awarded up to the year prior to which the outcome variable was assessed.

3.4.3. Total funds

We controlled for the total amount of cumulative funding the new ventures obtained up to the year prior to which the outcome variable was assessed. We constructed the *total funds* variable by leveraging fine-grained data pertaining to the different financing sources: family and friends, angel investors, venture capitalists, private placements, equity investments, and grants. We applied a logarithmic transformation to enhance the normality of this variable.

3.4.4. VC funding

Different funding sources have a differential impact on incubator firm performance. Here, funding obtained form venture capitalists takes on an important signaling role as it often bestows legitimacy upon the new venture (Stuart et al., 1999). For example, at some research universities, it is the policy of the office of technology licensing not to issue a license to a start-up unless it has obtained venture capital funding.[1] Therefore, to control for this important source of funding, we constructed an indicator variable that takes on the value of 1 if the technology firm received venture capital funding during any time prior to the year at which the outcome variable was assessed, and 0 otherwise.

3.4.5. Industry effects

Industry effects clearly impact new venture success, and thus, the probability of successful graduation. We tracked each firm's industry based on four digit Standard Industry Classification (SIC) codes. Since over 40% of the technology ventures in the sample are active in the software industry (SIC 7372), we included an indicator variable coded 1 if the new technology venture is a *software* company.

3.4.6. Time in incubator

While the sample is not prone to a survivor bias, we are faced with the problem of left censoring since

[1] This is not the policy at the Georgia Institute of Technology, however.

the ATDC technology incubator was in existence prior to 1998, the first year of our annual data collections. To ameliorate this problem, we recorded the year that each firm was admitted into the incubator, which generally coincides with the firm's founding date, and the last year the firm remained in the incubator. These two data points enabled us to construct the *time in incubator* variable, which is the number of years the firm remained in the technology incubator, to account for left censoring.

3.4.7. Non-GT Link

When assessing the impact of different types and permutations of Georgia Tech linkages on the performance of ATDC ventures in a fine-grained manner, it is critical to control for university linkages that the ATDC ventures may have to other, non-GT, research universities. In fact, the sample firms listed linkages to 11 US research universities besides Georgia Tech. To isolate the effect of different Georgia Tech linkages on the performance of ATDC ventures, we created an indicator variable that takes on the value of 1 if the firm had a link to a university other than Georgia Tech, and 0 otherwise. Some ATDC firms in the sample, for example, maintained linkages to universities other than Georgia Tech but did not have a link to Georgia Tech other than their membership in the ATDC.

3.5. Estimation procedure

We focus on the *performance outcome* of the technology ventures in the sample at $t+y$, thus, the dependent variable can take on three categories: failure, remaining in incubator, and successful graduation. Accordingly, we applied multinomial logistic regression, estimated with a maximum likelihood procedure. The outcome variable, P_j, is the probability of falling into one of the outcome categories based on a nonlinear function with three outcomes (Maddala, 1983):

$$P_j = \frac{e^{\beta'_j x}}{D} \quad (j = 1,\ 2,\ \ldots,\ m-1)$$

and

$$P_m = \frac{1}{D}$$

where

$$D = 1 + \sum_{k=1}^{m-1} e^{\beta'_j x}.$$

4. Results

We followed 79 firms incubated in Georgia Tech's ATDC over the 6-year period between 1998 and 2003. We assessed the performance of these firms at $t+y$, where $1 \leq y \leq 3$ years. We obtained an unequivocal outcome variable for all 79 firms, and found that 41 firms (52%) had failed, 23 firms (29%) had graduated successfully, while 15 firms (19%) remained in the incubator. The key independent variable of this study represents the venture's linkages to the incubator-sponsoring university, Georgia Tech. The data reveal that 11 firms (14%) were founded based on a Georgia Tech License, while 48 firms (61%) indicated that they had a Georgia Tech Link of any type (*informal or contractual or senior management*). Of the latter, 13 firms (16%) had an *informal GT Link only*, 17 (22%) had a *contractual GT Link only*, and 18 (23%) had exclusively a *senior management GT Link.* In eight firms was the inventor of the GT technology also the venture's founder or part of the incubator firm's senior management (10% of all firms and 73% of firms founded on GT Licenses). Moreover, in the year prior to which the performance of the incubator firm was assessed, the average start-up in the sample had 14 employees, 3 patents, accumulated a total funding of US$ 3.3 million, and spent a little less than 2.5 years in the ATDC.

The variance among the high-technology ventures in this sample is quite high, which enhances the validity of the results. Some firms graduated successfully within the first year of their ATDC membership, while others did not obtain this goal even after 6 years of membership in the technology incubator. While several firms had no employees besides the founder, one firm had 75 employees in their last year of ATDC membership. While many firms did not obtain any patents, one firm had been awarded 13 patents. While the majority of firms (67%) were able to obtain some external funding, one firm accumulated more than US$ 30 million during their tenure in the incubator. Table 1 displays

Table 1
Descriptive statistics and bivariate correlation matrix

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Remain in incubator	0.19	0.39																
2. Failure	0.52	0.50	−0.50															
3. Graduation	0.29	0.46	−0.31	−0.67														
4. Employees	13.73	16.15	−0.26	−0.07	0.30													
5. Patents	2.84	6.36	0.17	0.03	−0.17	−0.08												
6. Total funds	3,315,835	4,975,936	0.15	−0.25	0.14	0.33	0.12											
7. VC funding	0.46	0.50	0.08	−0.19	0.14	0.41	0.00	0.53										
8. Software	0.43	0.50	−0.09	0.02	0.06	0.17	−0.25	0.15	0.18									
9. Time in incubator	2.43	2.16	0.37	−0.03	−0.28	−0.25	0.41	−0.29	−0.23	−0.19								
10. Non-GT University Link	0.20	0.40	0.16	0.17	−0.32	−0.14	−0.06	0.04	−0.02	0.13	0.02							
11. GT License	0.14	0.35	0.36	−0.20	−0.10	−0.14	0.16	0.00	0.00	−0.28	0.26	−0.02						
12. GT Link (informal or contractual or senior management)	0.61	0.49	0.12	0.00	−0.11	0.01	0.23	0.23	0.11	−0.03	0.05	0.08	0.25					
13. GT Link (contractual or senior management)	0.44	0.50	0.15	−0.06	−0.07	0.02	0.31	0.27	0.10	−0.21	0.02	−0.01	0.30	0.72				
14. GT Link (informal only)	0.16	0.37	−0.04	0.09	−0.06	−0.02	−0.11	−0.06	0.01	0.23	0.04	0.12	−0.08	0.36	−0.40			
15. GT Link (contractual only)	0.22	0.41	−0.17	0.01	0.14	0.04	−0.08	0.22	−0.11	0.10	−0.22	0.04	−0.12	0.42	0.59	−0.23		
16. GT Link (senior management only)	0.23	0.42	0.35	−0.08	−0.22	−0.01	0.45	0.11	0.23	−0.35	0.24	−0.05	0.48	0.44	0.61	−0.24	−0.28	
17. GT Inventor in Senior Management	0.10	0.30	0.48	−0.18	−0.22	−0.11	0.20	0.08	0.11	−0.21	0.26	0.04	0.83	0.27	0.38	−0.15	−0.18	0.62

$N = 79$.

the descriptive statistics and the bivariate correlation matrix, while Table 2 depicts the regression results.

We would like to emphasize that the independent variables are characterized by a low bivariate correlation (Table 1). The bivariate correlation is generally well below 0.70, suggesting discriminant validity of the different university linkage variables (Cohen et al., 2003).[2] For example, when considering the university linkages in isolation, their bivariate correlation is below $r < 0.30$. A high discriminant validity of the independent variables is also reflected in the fact that the maximum variance inflation factor was 1.8, well below the suggested cut-off point of 10 (Kleinbaum et al., 1988). Therefore, multicollinearity did not affect our results.

We hypothesized that a link maintained by a technology incubator venture to the incubator-sponsoring university reduces the venture's probability of failure, but at the same time retards its timely graduation. We proposed that these effects are the more pronounced the stronger the link maintained to the incubator-sponsoring research university. We assessed these two hypotheses based on the results obtained in Table 2. Model 1 includes the control variables only, and represents the baseline model. In model 2, we added the indicator variable for a start-up based on a Georgia Tech License (*GT License*). In line with the first prediction, we find that a venture founded explicitly to commercialize a technology of the incubator-sponsoring university is significantly less likely to experience outright failure ($p < 0.05$; $\text{Exp}(B) = 2.20$). However, we fail to find support for the hypothesis of retarded graduation since start-ups based on Georgia Tech Licenses are no less likely to graduate within 3 years than incubator ventures not based on Georgia Tech technology.

When assessing the effect of the more general Georgia Tech linkages that the technology ventures may

[2] In two cases (bivariate correlations between (1) *GT Link—informal or contractual or senior management* and *GT Link—contractual or senior management* and (2) between *GT License* and *GT Inventor in Senior Management*) are the respective bivariate correlations above 0.70 (r = 0.75 and 0.83). These somewhat elevated bivariate correlations are expected since the two constructs each share by definition a significant amount of common variance. Nonetheless, they do not affect the result of this study in any way since the two pairs of constructs exhibiting elevated bivariate correlations are not included in the same regression models.

Table 2
Results of multinomial logit regression predicting incubator firm failure and graduation, with remaining in incubator as reference category

	Model 1		Model 2		Model 3		Model 4	
	Fail	Graduate	Fail	Graduate	Fail	Graduate	Fail	Graduate
Employees	0.670* (0.455)	0.679** (0.400)	0.618* (0.458)	0.678* (0.417)	0.685* (0.461)	0.688** (0.405)	0.684* (0.460)	0.694** (0.406)
Patents	0.379 (0.308)	−0.288 (0.609)	0.328 (0.323)	−0.305 (0.632)	0.368 (0.311)	−0.175 (0.608)	0.396 (0.317)	−0.166 (0.622)
Total funds	−0.999** (0.444)	−0.478 (0.478)	−0.972** (0.462)	−0.460 (0.487)	−1.036** (0.457)	−0.458 (0.484)	−0.985** (0.460)	−0.444 (0.484)
VC funding	−0.452 (0.399)	−0.150 (0.377)	−0.349 (0.405)	−0.116 (0.386)	−0.451 (0.400)	−0.148 (0.378)	−0.444 (0.399)	−0.140 (0.376)
Software	0.156 (0.348)	0.117 (0.340)	−0.034 (0.364)	0.033 (0.361)	0.159 (0.349)	0.137 (0.342)	0.110 (0.371)	0.084 (0.350)
Time in incubator	−0.956*** (0.408)	−1.011** (0.466)	−0.803** (0.404)	−1.003** (0.490)	−0.974*** (0.416)	−1.033** (0.467)	−0.959*** (0.410)	−1.038** (0.469)
Non-GT Link	0.208 (0.294)	−0.871** (0.408)	0.172 (0.304)	−0.922** (0.425)	0.205 (0.296)	−0.889** (0.413)	0.215 (0.295)	−0.883** (0.410)
GT License			−0.787** (0.447)	−0.162 (0.328)				
GT Link (informal or contractual or senior management)					0.106 (0.355)	0.161 (0.342)		
GT Link (contractual or senior management)							−0.091 (0.368)	−0.217 (0.353)
GT Link (senior management only)								
GT Link (contractual only)								
GT Inventor in Senior Management								
Pseudo R^2	0.40		0.43		0.40		0.40	
−2 LL	139.08		135.05		138.42		138.69	

	Model 5		Model 6		Model 7	
	Fail	Graduate	Fail	Graduate	Fail	Graduate
Employees	0.755* (0.487)	0.786** (0.438)	0.738* (0.491)	0.774** (0.439)	0.591* (0.459)	0.631* (0.415)
Patents	0.501* (0.341)	0.149 (0.579)	0.496* (0.338)	0.122 (0.593)	0.357 (0.333)	−0.158 (0.592)
Total funds	−1.014** (0.445)	−0.528 (0.482)	−1.056** (0.458)	−0.570 (0.487)	−0.946** (0.465)	−0.453 (0.495)
VC funding	−0.274 (0.438)	0.133 (0.408)	−0.235 (0.451)	0.170 (0.419)	−0.245 (0.412)	0.007 (0.394)
Software	−0.051 (0.383)	−0.142 (0.369)	−0.011 (0.391)	−0.124 (0.375)	−0.018 (0.362)	−0.015 (0.354)
Time in incubator	−0.882** (0.403)	−0.925** (0.446)	−0.861** (0.403)	−0.884** (0.452)	−0.765** (0.406)	−0.849** (0.465)
Non-GT Link	0.205 (0.302)	−0.911** (0.417)	0.193 (0.305)	−0.915** (0.419)	0.196 (0.304)	−0.886** (0.423)
GT License						
GT Link (informal or contractual or senior management)						
GT Link (contractual or senior management)						
GT Link (senior management only)	−0.448 (0.416)	−0.825** (0.426)	−0.395 (0.431)	−0.767** (0.438)		
GT Link (contractual only)			0.167 (0.376)	0.186 (0.363)		
GT Inventor in Senior Management					−0.796* (0.522)	−0.627* (0.461)
Pseudo R^2	0.43		0.44		0.44	
−2 LL	135.05		134.75		134.23	

Standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

have, we found that strong ties based on Georgia Tech faculty involvement in the venture's senior management had the most significant effect on retarded graduation. Model 3 assesses the effect of *any type of Georgia Tech linkage*, and reveals that having any type of link, without explicitly assessing the strength of the tie to the sponsoring university, is not significantly related to either the probability of the venture's outright failure or its successful graduation. Model 4 depicts the results for firms whose linkages go beyond informal contacts as they comprise *contractual linkages* with GT professors and/or GT professors as part of the venture's *senior management team*. The results indicate that these types of somewhat stronger linkages do not impact the probability of firm failure nor do they appear to retard a venture's successful graduation. These non-results provide an important observation because many studies do not disentangle different university linkages based on their strength and other characteristics of the venture–university relationship. These results, however, indicate that we ought to look at each type of linkage individually, as done explicitly in this study.

Therefore, model 5 assesses the impact of Georgia Tech professors in the venture's senior management team in isolation. We find that having a GT professor as a senior manager does not affect the venture's probability of outright failure, but it does significantly retard the venture's timely graduation from the incubator ($p < 0.05$; Exp(B) = 2.28). To assess the robustness of this finding against the other types of linkages, we included the variable for having a GT professor in the venture's senior management team (*GT Link–senior management only*) and the variable for maintaining a contractual relationship with a GT professor (*GT Link–contractual only*) simultaneously into model 6, while having an informal link to Georgia Tech (*GT Link–informal only*) servers as reference category. This approach allows us to isolate the effect of the GT senior management link on the start-up's performance more fully. As indicated in model 6, the results for having a GT professor on the incubator firm's top management team obtained in model 5 remain robust. When controlling for the different types of university linkages explicitly, we find that an incubator firm's link to the sponsoring university through inclusion of a GT professor in its top management team reduces the probability of successful graduation ($p < 0.05$; Exp(B) = 2.15).

Against the backdrop of the significant individual effects of the new venture holding a GT License (reduced likelihood of failure, model 2) or having a GT professor in its senior management team (retarded graduation, model 6), the results obtained in model 7 are particularly interesting. Here, we assessed how having a GT professor, who is also the *inventor* of the technology, in the venture's start-up company (which includes GT professors as firm founders) affects new venture failure and graduation. We find that a *GT Inventor in Senior Management* has a marginal significant effect on *both* new venture failure and successful graduation. Having a GT inventor in the venture's top management team, reduces the probability of outright failure ($p < 0.10$; Exp(B) = 2.22) and, at the same, retards the venture's timely graduation ($p < 0.10$; Exp(B) = 1.87).

4.1. Results of control variables

Some of the results for the control variables are also noteworthy. Incubator firms that grow faster, as proxied by their number of employees, are, not surprisingly, somewhat more likely to graduate in a timely fashion. As expected, incubator firms that are able to accrue more funding are less likely to fail altogether. Interestingly, the variable for an incubator firm's university linkages to other universities than the one sponsoring the incubator is consistently significant when predicting successful graduation. The results obtained across all models indicate that having a link to a university other than Georgia Tech, either in isolation or in addition to a Georgia Tech Link, significantly retards successful graduation, while it has no effect on outright failure. This finding highlights the importance of explicitly controlling for other university linkages when investigating the relationship between linkages to an incubator-sponsoring university and incubator firm performance.

Finally, the significance of the *time in incubator* variable in predicting both failure and graduation underscores the importance of controlling for time effects to mitigate the problem of left censoring. This finding could be viewed as a Markov process in which the likelihood of failure and graduation decreases over time, and commensurately increases the residual probability of remaining in the incubator. In addition, the *time in incubator* variable is highly correlated with firm age, and thus, inversely correlated with the unobservable probability of firm failure (Jovanovic, 1982). Alternatively, *time in incubator* could also be correlated with the embryonic nature of university technologies, which is not observable in our data.[3]

4.2. Robustness checks

Since 15 firms (19%) remained in the incubator at $t+y$, there is some right censoring in the sample when attempting to predict the probability of failure and successful graduation. In unreported regressions, we assessed the possibility whether this biased our results through applying a binary logit model on the reduced sample ($N=64$) for which we have either a negative (failure) or positive (graduation) outcome at $t+y$, where $1 \leq y \leq 3$ years, and found that the results remained robust.

Moreover, we defined successful graduation as either the new venture is a stand-alone going concern or was acquired at $t+y$. Among the 79 firms, only three (4%) were acquired at $t+y$. The results are robust to dropping the few acquisitions in the sample. This robustness check is prudent because acquisitions might be a sign of failure rather than success, in particular, when the firm is acquired short of liquation (Shane and Stuart, 2002). In this study, however, the three acquisitions in this sample appear to be reflecting success rather than failure based on input received in our interviews with ATDC managers.

We also investigated whether other industry factors play a role in predicting firm failure and graduation in some more detail. The 79 firms in the sample fall into 14 different industry categories based on four-digit SIC codes with 34 firms in software (43%), 13 firms in telecommunications (16%), 6 firms each in manufacturing and communications (8%), 5 in healthcare (6%), 3 Internet businesses (4%), 2 firms each in agriculture, biotechnology, environmental services, and general services (3% each), and 1 firm each in microelectronics, paper industry, robotics, and video industry (1% each).

We explicitly tested for industry effects by employing an indicator variable for software companies, and found no support. Likewise, there was no evidence of industry effects when employing a telecom industry dummy variable. It is also worth noting that these two industries make up about 60% of the entire sample, and thus, we are quite confident that any omitted industry effects did not bias the results. Moreover, we suggest that the results do not appear to be directly influenced by the Internet boom and bust in the late 1990s and early 2000s since only three firms in the sample are Internet firms.

In the analysis, we explicitly controlled for the time the firms spent in the incubator. Alternatively, we employed a variable *last year in incubator*, which tracks the last year prior to which the firm's outcome variable was assessed (i.e., year = t), to control for year effects. The results were consistent.

5. Discussion

In this study, we investigated the effect of different university linkages on incubator firm failure and graduation. In particular, we assessed the effect of a technology license from the sponsoring university and linkages to faculty of the sponsoring university on the probability of incubator firm failure and timely graduation from the incubator within 3 years or less. We suggested that an incubator firm founded to commercialize a technology from the sponsoring university based on an exclusive license might be less likely to experience outright failure due to strong IP protection, a quality signaling effect and potential inventor involvement in the new venture. Moreover, we suggested that this type of incubator firm might also be slower to graduate due to a potentially overly optimistic inventor and a technology that is likely to be embryonic in its development.

When highlighting linkages of university faculty to incubator firms, we hypothesized that faculty involvement reduces the likelihood of failure because it facilitates the transfer of tacit knowledge. This effect should be particularly pronounced if the inventor of the technology is also the firm founder or part of the firm's senior management team. Similar to the arguments advanced when relating a university license to timely graduation from the incubator, we suggested that faculty involvement may slow graduation mainly due to the early stage of the technology. With respect to both failure and graduation, we posited that the effect of

[3] We thank Professor Adams for sharing these valuable insights with us.

faculty involvement is the greater, the stronger the linkage to university faculty of the incubator-sponsoring university. In sum, the baseline hypothesis we investigated was that university linkages to the incubator-sponsoring university not only reduce the probability of firm failure, but also retard timely graduation.

We tested these notions on a longitudinal sample of 79 technology ventures incubated in Georgia Tech's Advanced Technology Development Center, a technology incubator, over a 6-year time frame (1998–2003). Overall, we found that a new venture's university linkages through a GT License and/or through having a GT professor on the firm's senior management team significantly reduce the new venture's chances of outright failure, but also retard the firm's graduation from the incubator to a significant extent. The fine-grained analysis applied allowed us to attribute the probability of reduced new venture failure to the venture being founded on a technology licensed from the university sponsoring the incubator, while retarded graduation stems from links to faculty from the incubator-sponsoring university. The results indicated that a new venture founded to commercialize a technology licensed from the incubator-sponsoring university (Georgia Tech) is 2.20 times less likely to fail outright than a new venture that is not based on a license of the incubator-sponsoring university. When disentangling the effects of different strengths of linkages between the incubator firm and the sponsoring university, we found that only strong ties matter when predicting graduation within 3 years or less. Analyzing different strengths of ties to the incubator-sponsoring university, ranging from informal ties to the university professors to having a professor in a senior management position, we found that an incubator venture with a Georgia Tech professor as part of its top management team is significantly less likely to graduate in a timely fashion. In particular, the average ATDC venture with a Georgia Tech professor at its helm was more than two times (2.15) as likely to not achieve successful graduation than an incubator firm led by professional management, for example.

In several instances, the inventor of the new technology was also the firm's founder and/or part of its senior management team. We therefore explicitly assessed inventor versus non-inventor effects on the probability of incubator firm failure and timely graduation. Here, we found that having a Georgia Tech inventor in the incubator firm's senior management reduced *both* the probability of outright failure and the likelihood of timely graduation from the incubator within 3 years or less. The cognitive bias of "bold optimism" potentially experienced by firm founders might be particularly prevalent among inventors turned entrepreneurs (Camerer and Lovallo, 1999), and thus, may explain why having an inventor in the incubator firms' senior management team retards both the probability of outright failure and the likelihood of timely graduation. Moreover, there appears to be a trade-off between the evidently necessary tight-coupling between the technology invention and the start-up through a strong university tie versus the explicitly stated goal of many technology incubators to graduate firms in a timely fashion (Linder, 2003).

While prior research highlighted the importance of a university start-up founder's ties to venture investors as critical in obtaining funding (Shane and Stuart, 2002), we focus on the ties of the incubator firm to the sponsoring university in predicting firm failure or graduation. The results contribute to the growing literature on university industry technology transfer, as well as to the literature on technology incubators. While the former has examined the role of university faculty or university alliances in the performance of new ventures, it has largely ignored incubator-based ventures (see for example, Nerkar and Shane, 2003; Rothaermel and Deeds, 2004; Zucker et al., 2002).

On the other hand, the literature on technology incubators has largely overlooked the effect of university ties, and in particular faculty ties, on firm performance (for reviews see Hackett and Dilts, 2004; Siegel et al., 2003). An exception is Mian's (1996) case study of six incubators (including ATDC) which examines the importance to member firms of having access to university faculty. His results, however, as well as those of Culp (1996), point to the main benefit of university-linked incubators as reputational, with member firms perceiving the highest value added as the "credibility" associated with the university connection. Both of these studies have certainly enhanced our understanding of some of the benefits of incubators for new ventures, yet, Mian (1996) and Culp (1996) rely on a small sample employing a qualitative descriptive method, and thus, lack econometric analysis.

In contrast, we relied on longitudinal, firm-level data, which allowed for testing hypotheses pertaining to the role of university faculty on incubator firm failure or graduation. Phan et al., 2005 highlighted, among others, the dearth of firm-level data for incubator firms and concluded that it is "difficult to conduct an econometric analysis of the antecedents and consequences of the performance of firms" in technology incubators, who play an increasingly important role in the innovation infrastructure and regional economic growth. In this study, we attempted to take a first step in closing this gap in literature on incubator firm-differential performance through explicitly highlighting the role of university linkages on firm failure and graduation.

5.1. Limitations and future research

Rather than interpreting the result that faculty involvement retards graduation, one could also view this result as indicating that the probability of incubator retention is higher if the start-up has a strong link to a faculty member of the incubator-sponsoring university, because remaining in the incubator allows faculty members to conveniently exercise the double role of university researchers and start-up managers due to geographic proximity as well as institutional linkages and networks. This is an interesting proposition with important policy implications, and thus, should be investigated in further research more thoroughly.

The advantages and disadvantages of the dataset underlying this study are important to note. It is the longitudinal nature of our data that allow us to examine the relationship of university linkages and incubator firm performance. As noted above, the lack of data has been a limitation to the literature on incubators, which, except for Westhead and Storey (1997), Siegel et al. (2003), Rothaermel and Thursby (2005), has been based on incubator-level data, one-time surveys, or qualitative descriptions. We were able to study incubator firm failure and graduation over time, yet the study's context was limited to one incubator due to the necessity of accessing the fine-grained, longitudinal data needed to conduct the econometric analyses required to test our hypotheses. While we thus control for incubator-idiosyncratic effects through drawing the sample exclusively from Georgia Tech's ATDC, one clear limitation of this approach is that we cannot draw implications for incubator differential performance as do Colombo and Delmastro (2002). Future research should attempt to rely on longitudinal surveys conducted in multiple incubators, preferably in and outside the US, to enhance the validity and generalizability of our findings. Such an approach would also help to clarify the issue of whether the results are idiosyncratic to a high-performing technology incubator at a top research institution or more broadly generalizable to the incubator population at a variety of universities.

Another potential limitation of this study concerns the sample selection. There is some debate in the literature of what type of firms seek membership in technology incubators. Some argue that incubator managers select on the most promising firms, while others suggest that incubators provide nothing but subsidies to otherwise failing ventures (for a discussion see Hackett and Dilts, 2004). Clearly, incubator managers appear to apply strict due diligence prior to admitting new members, and the ATDC is no exception. Yet, evidence from our field work with incubator managers and firm founders (both ATDC members and non-members) lead us to believe that incubator managers sample on promising firms that are in need of help and assistance. Thus, the typical technology venture admitted to an incubator is likely to be neither a firm that would otherwise have no chance to survive nor a firm that does not need any support. Thus, our results, as other incubator-firm performance research, has to be interpreted within this context.

More work is clearly needed to further disentangle the reasons for a reduced probability of failure and delayed graduation of technology ventures with strong university ties. Future research needs to delve deeper to see whether the reduction in failure and retardation of graduation is based on characteristics of the IP regime, the underlying technology, the university faculty, or a combination of thereof. Here, a focus on the inventor as firm founder is a necessary first step. Finally, successful and timely graduation does not guarantee long-term success. Future work should go beyond graduation, which is clearly an important milestone in the development of a new venture, and investigate the performance of these ventures post graduation.

5.2. Managerial and policy implications

The results seem to indicate that entrepreneurs and incubator managers need to be aware of the trade-off they might encounter when incubating a new venture that relies on a strong university link either through a technology license and/or having one or more university faculty as part of the senior management team. Incubated firms without such ties were more likely to fail but also more likely to successfully graduate within a timely manner. Perhaps, a balanced approach combining the necessary university link for some start-ups with professional managers might ameliorate some of these challenges (Franklin et al., 2001). The combination of professional management and a strong university linkage through a university license might reduce incubator firm failure, while still allowing for timely graduation from the incubator.

Since over 70% of the sample firms experienced a unequivocal outcome (i.e., either graduation of failure) within 3 years or less post-incubation, an explicit policy forcing graduation might be counter productive. One tentative recommendation concerning graduation policies flowing from these results, therefore, would be not to institute iron clad policies, but rather to make graduation decisions on a case-by-case basis.

Acknowledgements

We thank Tony Antoniades (of the ATDC), George Harker (Director, Office of Technology Licensing, Georgia Institute of Technology), and H. Wayne Hodges (Vice Provost for Economic Development and Technology Ventures, Georgia Institute of Technology) for their generous support and invaluable input. A prior version of this paper was presented at the 2004 Technology Transfer Society (T2S) conference. We thank the discussant, James Adams, and the session attendants for valuable input. We also thank the special issue editors, the anonymous reviewers, Jonathan Clarke, Irwin Feller, and Jerry Thursby for helpful comments and suggestions on earlier versions of this paper, and Shanti Dewi and Trace Hawkins for research assistance. All remaining errors and omissions are entirely our own. Thursby gratefully acknowledges research support from NSF SES 0094573.

References

Acs, Z.J., Audretsch, D.B., Feldman, M.P., 1994. R&D spillovers and innovative activity. Managerial and Decision Economics 15, 131–138.

Agrawal, A., Henderson, R., 2002. Putting patents in context: exploring knowledge transfer from MIT. Management Science 48, 44–60.

Audretsch, D.B., Feldman, M.P., 2004. Knowledge spillovers and the geography of innovation. In: Henderson, J.V., Thisse, J.-F. (Eds.), Handbook of Regional and Urban Economics, vol. 4. Elsevier, Amsterdam, pp. 2713–2739.

Audretsch, D.B., Stephan, P., 1996. Company-scientist locational links: the case of biotechnology. American Economic Review 86, 641–652.

Camerer, C.F., Lovallo, D., 1999. Overconfidence and excess entry: an experimental approach. American Economic Review 89, 306–318.

Cohen, J., Cohen, P., West, S.G., Aiken, L.S., 2003. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Erlbaum, Mahwah, NJ.

Cohen, W.M., Florida, R., Randazzese, L., Walsh, J., 1998. Industry and the academy: uneasy partners in the cause of technological advance. In: Noll, R. (Ed.), Challenges to Research Universities. The Brookings Institution, Washington, DC, pp. 171–200.

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2002. Links and impacts: the influence of public research on industrial R&D. Management Science 48, 1–23.

Colombo, M.G., Delmastro, M., 2002. How effective are technology incubators? Evidence from Italy. Research Policy 31, 1103–1122.

Culp, R. 1996. A Test of Business Growth through Analysis of a Technology Incubator Program. Unpublished Ph.D. Thesis, Georgia Institute of Technology.

Darby, M.F., Zucker, L.G., 2002. Going Public When You Can in Biotechnology. NBER Working Paper 8954.

Dechenaux, E., Goldfard, B.D., Shane, S., Thursby, M. 2003. Appropriability and the Timing of Innovation: Evidence from MIT Inventions. NBER Working Paper 9735.

Fama, E.F., 1980. Agency problems and the theory of the firm. Journal of Political Economy 88, 288–307.

Franklin, S.J., Wright, M., Lockett, A., 2001. Academic and surrogate entrepreneurs in university spin-out companies. Journal of Technology Transfer 26, 127–141.

Hackett, S.M., Dilts, D.M., 2004. A systematic review of business incubation research. Journal of Technology Transfer 29, 55–82.

Jaffe, A.B., Trajtenberg, M., Henderson, R., 1993. Geographic knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics 108, 577–598.

Jensen, R., Thursby, M., 2001. Proofs and prototypes for sale: the licensing of university inventions. American Economic Review 91, 240–259.

Jovanovic, B., 1982. Selection and the evolution of industry. Econometrica 50, 649–670.

Kalis, N., 2001. Technology Commercialization Through New Company Formation. National Business Incubation Association (NBIA) Publicatons, Athens, OH.

Kleinbaum, D.G., Kupper, L.L., Muller, K.E., 1988. Applied Regression Analysis and Other Multivariate Methods, second ed. PWS-Kent, Boston, MA.

Linder, S., 2003. 2002 State of the Business Incubation Industry. National Business Incubation Association (NBIA) Publicatons, Athens, OH.

Maddala, G.S., 1983. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge University Press, Cambridge, UK.

Mian, S.A., 1996. Assessing value-added contributions of university technology business incubators to tenant firms. Research Policy 25, 325–335.

Nerkar, A., Shane, S., 2003. When do start-ups that exploit patented academic knowledge survive? International Journal of Industrial Organization 21, 1217–1434.

Phan, P.H., Siegel, D.S., Wright, M., 2005. Science parks and incubators: observations, synthesis and future research. Journal of Business Venturing 20, 165–182.

Rothaermel, F.T., 2002. Technological discontinuities and interfirm cooperation: What determines a start-up's attractiveness as alliance partner? IEEE Transactions on Engineering Management 49, 388–397.

Rothaermel, F.T., Deeds, D.L., 2004. Exploration and exploitation alliances in biotechnology: a system of new product development. Strategic Management Journal 25, 201–221.

Rothaermel, F.T., Thursby, M., 2005. University-incubator firm knowledge flows: assessing their impact on incubator firm performance. Research Policy 34, 305–320.

Rosenwein, R. 2000. The Idea Factories. Inc., November.

Shane, S., Stuart, T., 2002. Organizational endowments and the performance of university start-ups. Management Science 48, 154–170.

Siegel, D.S., Westhead, P., Wright, M., 2003. Assessing the impact of science parks on the research productivity of firms: exploratory evidence from the United Kingdom. International Journal of Industrial Organization 21, 135–1369.

Stuart, T.E., Hoang, H., Hybels, R.C., 1999. Interorganizational endorsements and the performance of entrepreneurial ventures. Administrative Science Quarterly 44, 315–349.

Thursby, J., Jensen, R., Thursby, M., 2001. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities. Journal of Technology Transfer 26, 59–72.

Thursby, J., Thursby, M., 2003. University licensing and the Bayh-Dole act. Science 301, 1052.

Thursby, J., Thursby, M., 2004. Are faculty critical? Their role in university–industry licensing. Contemporary Economic Policy 22, 162–178.

Thursby, M., Thursby, J, Dechenaux, E., 2004. Shirking, Shelving, and Risk-Sharing: The Role of University License Contracts. NBER Working Paper 11128.

Tornatzky, L., Waugaman, P.G., Gray, D.O., 2002. Innovation U: New University Roles in a Knowledge Economy. Southern Technology Council.

Westhead, P., Storey, D.J., 1997. Financial constraints on the growth of high technology small firms in the United Kingdom. Applied Financial Economics 7, 197–201.

Zucker, L.G., Darby, M.R., Armstrong, J., 2002. Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. Management Science 48, 138–153.