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Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities☆

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Abstract

This paper adopts a resource-based perspective to understand why some universities are more successful than others at generating technology-based spinoff companies. In this respect, we derive eight hypotheses that link attributes of resources and capabilities, institutional, financial, commercial and human capital, to university spinoff outcomes. Using panel data from 1980 to 2001, our econometric estimators reveal evidence of history dependence for successful technology transfer to occur although faculty quality, size and orientation of science and engineering funding and commercial capability were also found to be predictors of university spinoff activity. We conclude by drawing implications for policy makers and university heads.

JEL classification: D24; L31; M13; O31; O32

Keywords: University entrepreneurship; Technology transfer; University spinoffs; Resource-based view

1. Introduction

Given the difficulties of established firms in bringing new technologies to the market (Utterback, 1994), U.S. universities are increasingly viewed as a source for the creation of high tech firms (Roberts, 1991). As a result, there is a growing need for universities to develop more 'rapid' linkages between science, technology and utilization (Allen and Cohen, 1969; Allen et al., 1979) and serve a 'third-mission' of contributing to local economic development (Etzkowitz, 2002). These developments are posing challenges to the traditional role of the university and its support practices towards entrepreneurial activities (Van Dierdonck and Debackere, 1988; Lerner, 2004).

The importance of the traditional university is well documented in the literature (Geiger, 1993; Bok, 2003).

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Their primary mission is to engage in research and disseminate knowledge across both academic and student communities. They also contribute indirectly to technology transfer activities by providing highly educated and qualified personnel to industry (Carayannis et al., 1998). According to Segal (1986), these universities not only provide a source of technical expertise for faculty members, but their students also acquire a wealth of codified and tacit knowledge through learning and living at the university.

However, across national economies there is a need for more emphasis to be placed on transferring and commercializing knowledge generated within universities (Cohen et al., 1998). More specifically, there is a growing need for universities to disseminate the knowledge generated beyond the narrow confines of the academic community itself (Mansfield and Lee, 1996; Branscomb et al., 1999; Hague and Oakley, 2000). As a result, many universities are now playing a third role in society through actively converting new scientific discoveries into spinoff opportunities (Kinsella and McBrierty, 1997; Leitch and Harrison, 2005). In essence, these 'entrepreneurial' oriented universities, as coined by Etzkowitz (1998), are proving key for regional economic development, going beyond the provision of graduates and research. Although some authors refer to the spinoff strategies of different European public research-based institutions (Klofsten and Jones-Evans, 2000; Davenport et al., 2002; Clarysse et al., 2005), the case of Massachusetts Institute of Technology (MIT) is the reference example (Roberts and Malone, 1996; Lüthje and Franke, 2003). By encouraging faculty members to pursue private ventures outside the research lab, Bank Boston Economics Department, 1997 has calculated that MIT start-up companies generate 232 billion dollars worth of sales per year to the U.S. economy. University spinoffs are an important subset of start-up firms because they are an economically powerful group of high technology companies (Shane and Stuart, 2002; Heirman and Clarysse, 2004). According to the Association of University Technology Managers (AUTM), spinoffs from American academic institutions between 1980 and 1999 have contributed 280,000 jobs to the U.S. economy.

The recent plethora of studies on university spinoffs can be divided into three main categories. The earliest research regarding the topic assesses the personal characteristics of academics that appear to impact entrepreneurship. For example, Roberts (1991) found the average MIT technical entrepreneur typically exhibited a high desire for independence, a moderate need for achievement and a low need for affiliation. In a more recent exploratory study at MIT, Shane (2004a) uncovered motivational characteristics, such as (1) a desire to bring technology into practice; (2) a desire for wealth and (3) a desire for independence, as key 'pull' and 'push' factors impacting academic spinoff behavior. Furthermore, Zucker et al. (1998) found scientific 'stars' collaborating with firms had substantially higher citation rates than pure academic stars.

The second strand of spinoff literature assesses the influence of universities' policies, procedures and practices on commercialization. Some studies found that the perceived responsiveness of university policy may affect whether academics attempt to exploit intellectual property (IP) within or outside the perimeters of the university (Feldman et al., 2002; Degroof and Roberts, 2004). Beyond this, Clarke (1998) in a cross-national study of five highly successful European universities identified entrepreneurial culture as a key element for successful University Industry Technology Transfer (UITT, as coined by Siegel et al. (2003)). In addition, Siegel et al. (2004) propose that in order to foster a climate of entrepreneurship within U.S. academic institutions, university administrators should focus on five organizational and managerial factors. These are reward systems for UITT, staffing practices in the technology transfer office (TTO), designing flexible university policies to facilitate university technology transfer, devoting additional resources to UITT and working to eliminate cultural and informational barriers that impede the UITT process. Debackere and Veugelers (2005) also supports this view and postulates that universities should employ (1) incentive structures to reward academic entrepreneurial endeavors; (2) decentralized operating structures to provide greater autonomy to research teams and (3) a centralized staff of experienced technology transfer personnel to manage the 'contract' and 'training' issues associated with the technology transfer process.

A third strand of the spinoff literature explores environmental factors impacting academic innovations (Mowery et al., 2001). According to Shane (2004b), a significant impetus in the generation of spinouts in the U.S. was the enactment of the Bayh–Dole Act, whereby inventions were assigned to academic institutions rather than individual inventors. Beyond this, Florida and Kenney (1988) highlight the central role venture capital plays in encouraging the formation of high technology companies. Knowledge infrastructure of a region is also cited as a key factor. For example, Saxenian (1994) found that spinoff activity is more likely to occur in high technology clusters because access to critical expertise, networks and knowledge is readily available.

While these studies have advanced our understanding of spinoff behavior, a number of scholars have pointed out deficiencies in the literature. First, most studies have explored the effects of individual, institutional or environmental factors on university spinoff behavior (Nicolaou and Birley, 2003). As a result, a distinct void exists with respect to the organizational factors accounting for variability in university spinoff activity. Second, the literature has been primarily atheoretical and non-cumulative in that most writers have developed conceptual models that are not empirically tested or make conclusions based on case studies (Djokovic and Souitaris, 2004). Third, while a number of studies have investigated knowledge flow effects from universities to industry (Agrawal and Henderson, 2002; Siegel et al., 2003a,b) and university technology transfer performance (Henderson et al., 1998; Thursby and Kemp, 2002; Siegel et al., 2003a,b; Chapple et al., 2005), few studies have systematically attempted to explain why some universities are more successful than others at generating technology-based spinoff companies (Shane, 2004a; Wright et al., 2004a; Lockett and Wright, 2004).

This study aims to address these limitations by investigating the impact of internal characteristics on university spinoff activity. The contribution of this article is our focus on university resources and capabilities explaining variation in spinoff behavior.

2. Theoretical development

The founding idea of viewing a firm as a bundle of resources was developed by Penrose (1959). She argued that firms derive their advantages from market imperfections. Therefore, it is the heterogeneity, not the homogeneity, of resources that give each firm its unique character (Lockett and Thompson, 2001, 2004). This notion of a firm's resource heterogeneity is the foundation of the resource-based view (RBV). The importance of the RBV perspective in the management science field was recognized by a seminal article by Wernerfelt (1984). He argued that sustained competitive advantage can originate in a firm's resource base, and thereby focused attention on the internal workings of an organization.

Drawing on Wernerfelt's work, we categorize four types of tangible and intangible resources, institutional, human capital, financial and commercial, and we then investigate what role the resource-capability[1] link plays in explaining inter-institutional variations of university spinoff activity. Consistent with DiGregorio and Shane (2003), university spinoff activity is measured by the number of spinoff companies generated by the university on an annual basis as measured by the Association of University Technology Managers.

2.1. Institutional resources

The uniqueness of historical conditions, whereby firms are intrinsically historical and social entities, can be the basis for sustained competitive advantage. According to Barney (1991), if a firm obtains valuable and rare resources because of its unique path through history, it will be able to exploit those resources in implementing value-creating strategies that cannot be duplicated by other firms. Teece et al. (1997) also propose that the past histories of firms make them unique and constrain what they can do in the future. Such "path dependencies", gives the firm its current set of capabilities and a position relative to its competitors.

In the spinoff literature, Golub (2003) supports this historically dependent perspective and credits the growth in spinoff activity at Columbia University, at least, in part, to the knowledge spillovers provided by academic inventors in Life Sciences who had established companies in the early 1990's. Shane (2004b) supports the view that faculty members' decisions to start companies in MIT were socially conditioned. According to the author, efforts by pioneering entrepreneurial faculty members to found start-ups

[1] Consistent with Wernerfelt (1984, 1995) and Barney (1991), we use the term resources and capabilities as bundles of tangible and intangible assets tied semi-permanently to the firm.

later proved beneficial because it led new academics to believe that firm formation was an acceptable and desirable activity.[2]

According to this perspective, knowledge accumulation inherent in the process of generating university spinoffs influences a university's future ability to produce university spinoff companies. Hence, we put forward the following proposition.

H_1. Universities that have a tradition and history of spinning out technology-based companies are more likely to be successful generators of spinoff activity.

2.2. Human capital

Research has shown that a critical human capital resource for the development of cutting-edge technologies is access to persons with expert knowledge and talent (Powers and McDougall, 2005). Zucker et al. (1998) argues that 'star' scientists from higher quality academic institutions create spinoff firms to capture the rents generated by their intellectual capital. Such capital is tacit and, therefore, it is difficult for lower quality institutions to imitate. DiGregorio and Shane (2003) suggest faculty members who develop leading edge innovations may wish to earn economic rents on valuable asymmetric information. They suggest it may be easier for academics from top tier universities to assemble resources to create start-ups due to their increased credibility. DiGregorio and Shane (2003) provide support for this proposition by examining the spinoff rate of 101 U.S. universities from 1994 to 1998 and found that ceteris paribus, a one-point increase in a university wide quality ranking as measured by the Gourman Report led to a 68% increase in the spinoff rate. Therefore, we postulate.

H_2. A high quality rating of a university's science and engineering departments will positively impact the number of spinoff companies created.

In addition, the relationship of human capital resources to technology transfer can be significant. According to Powers (2003), one of the necessary conditions for the generation of start-ups from universities is the availability of scientists and engineers with suitable qualifications and know-how in R&D activities. The availability of human capital implies higher skills and knowledge within a university, which is positive for the realization of technology transfer activity. Therefore, we assume university spinoff activity to be influenced by the availability of scientists and engineers with appropriate knowledge and inclination. Hence:

H_3. The number of postdoctoral staff and faculty working in research and development activities will positively impact the number of spinoff companies formed.

2.3. Financial resources

There is a body of empirical research that supports the view that increased university–industry ties and closer partnerships with industry result in greater levels of commercialization. Blumenthal et al. (1996) surveyed 2052 faculty at 50 universities in the life sciences field and found that industry funded faculty members are more commercially productive (i.e. patent applications and new products brought to the market) than those who are not industry funded. In a cross-sectional study of Carnegie I and II universities, Powers and McDougall (2005) also found a positive and statistically significant relationship between annual university-wide R&D expenditure and spinoff activity. Furthermore, Wright et al. (2004b) found evidence to suggest that involvement of industry, such as venture capitalists via joint venture spinoffs, may facilitate the emergence of university spinoffs because they have the necessary financial resources and commercial expertise to transfer technologies successfully to the marketplace.

Given that good universities tend to obtain a larger amount of industry-funded research, we argue that the use of absolute magnitude of money from industry as a measure may cause a multicollinearity problem with the variable that measures research quality of universities. Therefore, the strength of university ties with industry is measured by the proportion of research funding money rather than the absolute sum of money from industry. We, therefore, put forward the following hypothesis.

[2] Shane (2004a) refers to entrepreneurial learning effects that occur over time amongst and between academics within universities as the "contagion effect".

H_4. The greater the proportion of industry-funded research received by the university as a proportion of total research and development funding the greater the propensity to spinoff firms.

Despite the growth of industry sponsored academic research National Science Foundation (NSF, 1991–2001), the vast majority of support comes from a small number of federal agencies in the U.S. In particular, these include the National Institutes of Health, National Science Foundation, Department of Defense, Department of Energy and the Department of Agriculture (Etzkowitz, 2002). However, there is a growing concern amongst these federal agencies regarding the increasing cost of funding university-based research. There is also an increasing need to obtain value for money for public expenditure allocated towards higher education (OECD, 1998). Therefore, universities are now expected to become more efficient in their use of public resources and more accountable. These pressures have made research evaluation a central issue. As a result, a number of these agencies are now actively looking for more direct knowledge spillover effects in terms of increased productivity and employment.

The nature of university research and the industries where spinoff companies are more likely to emerge has gained prominence in the literature of late. For example, Shane (2004a) reports that the majority of MIT spinoff companies from 1980 to 1996 operated in the biomedical industry. Similarly, Golub (2003) found that half of all spinoff companies that emerged from Columbia University derived from biomedical research while the remainder came from the electronics and software fields. Furthermore, Shane (2001) provided a framework of favorable market preconditions for technology transfer to occur successfully. Using data from MIT patents, Shane demonstrated that the tendency for an invention to be exploited through firm creation varies with the attributes of the technology. These attributes include: (1) age of the technical field; (2) the tendency of the market towards segmentation; (3) the effectiveness of patents and (4) the importance of complementary assets. These studies suggest that "relevance of research" (Geiger, 1993) with regard to the life cycle of industries may play a key role in explaining variation in university spinoff activity. These studies lead us to pose the following hypotheses.

H_5. Universities with a larger science and engineering budget are more likely to generate spinoff companies from university research.

H_6. The greater the proportion of federal funds allocated to life science, computer science and engineering disciplines the greater the propensity of universities to spinoff firms.

2.4. Commercial resources

Commercial resources have been recognized in the innovation management literature as complementary resources for the appropriation of research results (Teece, 1986). The technology transfer office plays a key role with respect to engendering academic entrepreneurship. First, they may engineer synergistic networks between academics and venture capitalists, advisors and managers who provide the human and financial resources that are necessary to start a company. Second, they provide company formation expertise as many technology transfer personnel have experience in evaluating markets, writing business plans, raising venture capital, assembling venture teams and obtaining space and equipment (Chugh, 2004).

It takes time to establish a portfolio of invention disclosures, patents and to sell licenses and create start-ups. Cultural barriers exist between the TTO, the university scientists and industry (Friedman and Silberman, 2003) and providing incentives to encourage a climate of academic entrepreneurship takes time and effort (Siegel et al., 2003a,b). Therefore, we argue the number of full-time equivalents (FTE's) engaged in encouraging technology transfer within universities is an important determinant to successful technology transfer. Hence:

H_7. Universities that have more people resources (FTE's) dedicated to the technology transfer effort will have a greater propensity to spinoff firms.

An alternative measure of commercial resources is the existence of a formal incubator in the university (Mian, 1996). Although university spinoffs can be generated in many ways, the existence of a formal function such as an incubator inside the university indicates importance to the activity. According to

Smilor and Gill (1986), the advantages of academic entrepreneurs locating within a university incubator include: (1) access to library facilities; (2) access to student labor; (3) a creative environment and (4) exposure to state-of-the-art facilities and expertise. Similarly, Tornatzky et al. (1996), while identifying 50 best practice incubator programs in the U.S., highlighted the role technology incubators could play in accelerating the technology transfer. According to the authors, technology incubators provide the role of uniting technical, managerial and venture capital skills to facilitate new venture formation (Mian, 1996). Hence:

H_8. The presence of a university-affiliated incubator will be positively related to spinoff activity.

3. Research method

3.1. Sample and data collection

The data for this study was obtained through database and survey sources on 141 U.S. universities. Our dependent variable is the number of university spinoff companies created and was obtained from the AUTM survey. This, to our knowledge, is the only comprehensive and national source of data on technology transfer activity. The AUTM is characterized by some missing observations on the variable of interest. To be included in the sample, a university needs to have provided at least two observations (including zero) over the period 1995–2001.[3] This approach, which limits sample selection bias, is consistent with a previous study undertaken by DiGregorio and Shane (2003).

Input data was obtained from a variety of databank sources, including the National Science Foundation, National Research Council (NRC, 1995), United States Patent and Trademark Office (USPTO), Association of University Technology Managers and *TheCenter Research Institute for university performance*. To obtain information regarding the presence of university incubators on university campuses, we also conducted a survey of TLO directors of universities.

Our sample consists of 987 (141 × 7) university-year observations. Although the precise number of spinoffs in a given year in the U.S. is unknown, the sample appears to account for the vast majority of the population of such firms (DiGregorio and Shane, 2003). Therefore, selection bias should not hinder analysis.

3.2. Dependent variable

The dependent variable is a count number of the spinoff companies generated at university i at time t and was sourced from the AUTM survey.

3.3. Predictor variables

3.3.1. Institutional resources

To test our dependence on history hypothesis, we draw directly from the work developed by Blundell et al. (1995). These authors argue that a key explanation for the source of unobserved heterogeneity of innovation activity amongst firms (in our case, universities) lies in the different past knowledge stocks that reside within them. According to this perspective, knowledge accumulation from the past generates benefits in the present and future, therefore making spinoff creation a path-dependent process.

Blundell et al. (1995) propose a technique to parameterize a part of unobservable heterogeneity that accounts for history and tradition. One parameterizes the level of knowledge accumulation activities in a pre-sample ($BEFORE_i$) period. The search activity measure is based on the idea that the average patent search level will be proportional to the unobservable university specific effect. According to the authors, over a long enough time span, the number of actual spinoffs generated should be a reasonable proxy for average search activities, enabling us to proxy the individual unobservable heterogeneity by a pre-sample measure of spinoff counts. In this study, we use a measure of pre-sample spinoffs between 1980 and 1994 ($BEFORE_i$) as a proxy for past knowledge accumulation activities.

[3] Information on spinoff counts is missing for 14% (139/987) of the observations for the selected universities. Forty-seven percent (68/141) of the 141 institutions have at least 1 year for which the dependent variable is missing. We implement various strategies to deal with missing observations. The first is to assume missing observations are in fact zero. The second strategy replaces missing observations with the mean number value of yearly spinoffs for these universities. The third approach is to drop all universities with incomplete records. Results for the three different estimation strategies do not vary substantially, which supports our view that we observe a representative sample of U.S. institutions and the recoding of missing observations is not an issue.

This variable is used in our study to test for evidence of persistence of spinoff activity "between" pre-sample and current sample time periods.

The second measurement uses a dynamic learning measure of spinoff production to proxy for the knowledge spillovers "within" the current sample time 1995–2001. Consistent with Blundell et al. (1995), we use the assumption that previous spinoff counts provide knowledge about the spinoff process, but that the quality of this knowledge depreciates over time. This measure is based on an AR (1) model with a parameter set at 0.7, equivalent to a depreciation rate of 30% per year.

Denoting spinoff creation at period t by S_t this process can be parameterized as:

$$S_t = 0.7S_{t-1} + \varepsilon_t$$

$$\text{which is equivalent to}: S_t = \sum_{i=0}^{t-1} 0.7^i S_i + \varepsilon_t$$

For the initial value of the process S_0, we use the number of spinoffs in the year 1994.[4]

3.3.2. Human capital

To measure the number of postdoctoral students and faculty members aligned to R&D in each university, we relied on the National Research Council databank. With respect to quality ranking of science and engineering faculty, we utilized the rating of science and engineering scores provided by the National Research Council. The Faculty Quality surveys by federal authorities take place on average every 10 years. The data was published in 1995. The faculty quality index scores ranges from a low of 1.0 to a maximum of 5.0.

3.3.3. Financial resources

For the purposes of this study, we measure the total amount of the science and engineering budget through the National Science Foundation official science and engineering statistics databank. To measure whether the nature and type of federal funding effects, we categorize the data into the disciplinary categories of physics, chemistry, engineering, life science, agricultural science, computer science and environmental science. The relative industry R&D revenue variable in this study represents the percentage of total R&D revenues that derive from industry within a given year. The data was obtained from the National Science Foundation annual surveys on academic research and development expenditures between 1993 and 1999.[5]

3.3.4. Commercial resources

To measure the number of commercial resources dedicated to technology transfer efforts, we measure the number of years that the office had full-time equivalent dedicated professional technology transfer staff. This data is collected on an annual basis by AUTM. To measure whether the university had an affiliated incubator, we surveyed TLO directors and asked whether the university provided access to a university-affiliated incubator.

3.4. Control variables

In addition, we controlled for alternative explanations for university spinoff activity.

3.4.1. Presence of medical school

The presence of a medical school effect is based on the proposition that medical inventions have greater marketability than inventions from other disciplines (Powers, 2003). This data was collected from *TheCenter Research Institute for university performance*.

3.4.2. Institutional type

Institution type may be related to the culture of the university with respect to encouraging university spinoff activity. Institutional type variables are measured by dummy variables for the Public Private nature of the institution and also the presence of a Land-Grant infrastructure. Land-Grant institutions may be more likely to follow their traditional mission and produce knowledge that is used by industry. (Friedman and Silberman, 2003). Data regarding institutional variables were obtained from *TheCenter Institute for university performance*.

[4] Results are not sensitive to this choice of parameter. We tested parameters in the range 0.5–0.9 and obtained similar results.

[5] NSF databank does not provide detailed discipline breakdown figures for industry science and engineering funding.

3.4.3. Regional environment

Much of the empirical research suggests that the contributions of university-based research tend to be geographically concentrated. As a consequence, a university's ability to generate spinoff companies may depend on knowledge spillovers from the industry sector (Friedman and Silberman, 2003). To measure the degree of industrial infrastructure in U.S. regions, we draw from the Milken Institute Regional Ranking survey produced in 2000.[6]

3.4.4. Patenting activity

Given that the number of spinoff companies produced may be related to the number of inventions produced by the University (DiGregorio and Shane, 2003), we control for the number of patents issued to the USPTO.[7]

3.4.5. Endowment funds

To measure university endowment, we obtained data from the *TheCenter Research Institute for university performance*. Endowment level is used as a proxy measure to control for overall wealth of the university.

3.5. Model specification and estimation

To test the degree to which university spinoffs are affected by different sets of resources, the following model is estimated:

$$Y_{it} = f(\beta_0 + \beta_1 HIST_{i-t} + \beta_2 HUMCAP_{it-r} + \beta_3 FIN_{it-r} + \beta_4 COMM_{it} + a_i + n_i + v_t)$$

where Y_{it} is the count of spinoff companies produced in university i at time t and is a function of financial (FIN_{it-r}) and human Capital inputs ($HUMCAP_{it-r}$) into the research process, technology transfer infrastructure associated with the university commercialization effort ($COMM_{it}$) and the extent to which the university exhibits a successful history and tradition at spinoff activity representing the dynamic feedback ($HIST_{i-t}$). a_i are university specific control variables and $n_i + v_t$ represent university and time unobservable differences. As explained above, two strategies are used to measure the historical component (Foltz et al., 2003), either the count of spinoffs in previous period or an AR (1) process representing the dynamic feedback effect in current sample period (G_{i-t}).

According to Hausman et al. (1984), there are two ways to deal the discrete nature of count data: the Poisson regression model or the negative binomial model. The Poisson distribution assumes that the mean and variance of the process are equal. This assumption is violated when over-dispersion (under-dispersion) of the data is observed. Among the reasons that may lead to the violation of this assumption are unobserved heterogeneity and a high frequency of zeros in the data (Cameron and Trivedi, 1998). In essence, the negative binomial model provides a solution to the problem of a skewed distribution by assuming a gamma distribution for the conditional mean of the dependent count variable, and therefore allows the conditional mean and variance to vary. In our case, a goodness-of-fit test rejected the Poisson distribution assumption, indicating a zero inflated distribution, so we utilize negative binomial models for this study.

Assuming unobserved heterogeneity is randomly distributed across universities (Hausman et al., 1984) we rely on a random effect model. The reason that guides our choice is that our data exhibits highly skewed distributions and as such many universities generate no spinoffs in a given year or over consecutive periods of time. This rules out a fixed effects model. The model was adjusted according to the method of estimation by maximum likelihood.

4. Results

Table 1 provides an analysis of the spinoff rankings of U.S. universities. In this dataset, the Massachusetts Institute of Technology achieved the highest ranking for all universities in the U.S. MIT generated a total of

[6] The Milken State Technology and Science Index encapsulates for each U.S. state an inventory of technology and science assets that can be leveraged to promote economic development. The criteria include research and development dollars, the population's percentage of advanced degrees, number of patents issued, venture capital investment, business starts and IPO proceeds, all indicators of future high-tech growth.

[7] An alternative measure of innovation would be to use invention disclosures (ID's) instead of patent counts to control for the production of technology within the perimeter of universities. For example, Siegel et al. (2003) found that ID's and not patents are a key intermediate input based on their field research interviews at five major research universities.

Table 1
Spinoff rankings of top 20 U.S. universities 1980–2001

Rank 1995–2001	University	Total no. of spinoffs 1980–2001	No. of spinoffs 1995–2001	No. of spinoffs 1980–1994	Rank 1980–1994
1	Massachusetts Institute of Technology	218	132	86	1
2	University of California System	148	118	30	7
3	Stanford University	101	73	28	8
4	California Institute of Technology	69	67	2	82
5	University of Washington	74	51	23	12
6	University of Minnesota	85	49	36	5
7	University of Michigan	60	42	18	15
8	University of Georgia	65	41	24	11
9	University of Utah	102	40	62	2
10	Johns Hopkins University	48	35	13	27
11	State University of New York (SUNY)	48	34	14	23
12	University of Southern California	34	32	2	82
12	Penn State University	49	32	17	18
14	University of Pennsylvania	48	31	17	18
15	Purdue Research Foundation	33	29	4	64
15	North Carolina State University	32	29	3	72
15	Columbia University	37	29	8	38
15	University of Virginia	38	29	9	35
19	Georgia Institute of Technology	42	28	14	25
19	Iowa State	45	28	17	18

Source: AUTM Licensing Survey FY 1980–2001.

218 spinoffs including 132 in the 1995–2001 period. This compared to University of California System and Stanford, which ranked second and third producing 118 and 73 spinoff companies within the 1995–2001 period, respectively. In terms of spinoff rankings, a number of interesting findings are worth nothing. First out of 141 universities, 11 of the top 20 spinoff performing universities in 1980–1994 period ($BEFORE_i$) continued to be among the top 20 spinoff producers in the current sample period 1995–2001. Second, in terms of new entrants only two universities outside the top 20 in the prior ($BEFORE_i$) period (i.e. California Institute of Technology and John Hopkins University) managed to break into the top 10 ranking in the subsequent 1995–2001 period. It is also worth observing that only four universities ranked outside the top 40 in the 1980–1994 period entered into the top 20 rankings in the subsequent 1995–2001 period. This hysteresis in the ranking suggests the existence of some path dependency.

Table 2 presents a breakdown of the count number of spinoff companies generated by the top U.S. universities within the current sample period 1995–2001. It is worth nothing that three of the top five universities maintained a top 5 ranking for all seven-time periods of observation. Stanford achieved a top 5 ranking for 4 out of 7 years and a top 10 ranking for the years 2001 and 2002. Universities with a ranking between 6 and 20 recorded an average production rate of 4.89 spinoffs per year.

Table 3 presents the summary statistics. From the 141 universities analyzed in our study, an average of two spinoffs were generated on an annual basis over the time period 1995–2001. The highest number of spinoffs generated per year was recorded by MIT producing a total of 31 spinoffs in 2000.

In Table 4, the results of the random-effects negative binomial estimations for university spinoff outcomes are illustrated. Utilizing Blundell et al. (1995), three models were estimated in this study: (a) a base model with no dynamic learning effects; (b) a dynamic knowledge model using prior period knowledge accumulation data between 1980 and 1994 ($BEFORE_i$) and (c) a model using continuous spinoff learning effects

Table 2
University spinoff performance of top 20 U.S. universities 1995–2001

University	1995	1996	1997	1998	1999	2000	2001	Total
Massachusetts Institute of Technology	13	6	17	19	17	31	29	132
University of California System	11	11	13	19	13	26	25	118
Stanford University	2	14	15	9	19	8	6	73
California Institute of Technology	4	10	9	11	7	14	12	67
University of Washington	5	3	25	8	n/a	6	4	51
University of Minnesota	6	2	6	8	5	11	11	49
University of Michigan	1	8	6	5	2	8	12	42
University of Georgia	5	6	5	7	5	7	6	41
University of Utah	2	6	6	5	8	10	3	40
Johns Hopkins University	2	2	3	5	7	10	6	35
SUNY	3	7	5	7	3	4	5	34
University of Southern California	3	3	4	2	4	7	9	32
Penn State University	4	3	9	5	3	4	4	32
University of Pennsylvania	7	4	4	4	6	6	n/a	31
Purdue Research Foundation	2	3	1	4	4	5	10	29
North Carolina State University	3	n/a	1	5	8	6	6	29
Columbia University	0	1	4	5	5	7	7	29
University of Virginia	0	1	3	2	6	10	7	29
Georgia Institute of Technology	2	0	0	9	3	6	8	28
Iowa State	4	4	6	5	2	5	2	28

Source: AUTM Licensing Survey FY 1995–2001.

within current sample period 1995–2001 (G_{t-1}). With the use of panel data, a key finding of our paper is evidence that history and tradition matters in explaining university spinout outcomes. In particular, the coefficients for both our historical dependence measurement models (1) knowledge accumulation ($BEFORE_i$) and (2) continuous dynamic effects (G_{t-1}) show positive and significant effects ($p < 0.001$ and $p < 0.01$ levels), respectively.

In terms of faculty quality ($FACQUAL_{it-3}$), all three models have coefficients that are positive and statistically significant ($p < .01$, $p < .05$ and $p < .01$), respectively. However, the number of postdoctoral ($POSTDOC_{it-3}$) and faculty members ($FACULTY_{it-3}$) did not show to be significant for four of the six models tested. This indicates that it is investment in quality rather than quantity of human capital resources that matters in determining university spinoff activity.

The size of federal funding in science and engineering ($SEFED_{it-3}$) show results that are positive and statistically significant ($p < .01$, $p < .001$, $p < .001$) for all three models. As one might expect, our findings also support the view that some disciplines are more effective than others at generating spinoffs. For example, universities that receive a greater proportion of their research funding within the life sciences ($pFEDLIFESCI_{it-3}$), chemistry ($pFEDCHEM_{it-3}$) and computer science ($pCOMPSCI_{it-3}$) disciplines have a greater propensity to spinout university start-ups.

In addition, our findings also concur with previous studies that universities who attract a greater proportion of funding from industry have a greater tendency to spinoff companies. The coefficients of the variables associated with technology transfer office employees (*TTOSIZE*) are statistically significant ($p < .01$, $p < .05$ and $p < .05$ levels, respectively) in the expected directions. However, the presence of a university-affiliated incubator was not significant in our study.

In summary, our study reveals (1) previous success in technology transfer; (2) a high faculty quality NRC index rating; (3) a strong science and engineering funding base with an orientation in life science, chemistry and computer science disciplines; (4) a relatively high percentage of industry funding and (5) a strong commercial resource base all have positive values that are statistically significant. Thus, an increase in any of these variables is likely to increase the number of spinoff companies generated by a university.

Table 3
Summary statistics for period 1995–2001

Variables	Definition	Observation	Mean	S.D.	Minimum	Maximum	Data source
Y_{it}	Count number of university spinoff companies	987	1.91	3.20	0	31	AUTM
$FACQUAL_{it-3}$	Quality rating index of science and engineering departments (1–5 rating index)	987	2.86	.73	1.19	4.7	NRC
$POSTDOC_{it-3}$	Number of R&D postdoctoral staff (university wide)	987	245.70	469.82	0	5036	NSF[a]
$FACULTY_{it-3}$	Number of faculty (university wide)	987	883.83	786.88	45	8176	NSF
$SEFED_{it-3}$	Total science and engineering federal funding (US$ 000)	987	32376	44.79	54	1335579	NSF
$pCOMPSCI_{it-3}$	Computer science federal funding (%)	987	5.61	9.73	0	65.9	NSF
$pFEDPHY_{it-3}$	Physical science federal funding (%)	987	16.93	18.75	0	96.08	NSF
$pFEDCHEM_{it-3}$	Chemistry federal funding (%)	987	2.40	3.89	0	32.77	NSF
$pFEDENG_{it-3}$	Engineering federal funding (%)	987	26.26	23.51	0	95.42	NSF
$pFEDCOMPSCI_{it-3}$	Environmental science federal funding (%)	987	14.64	19.91	0	96.08	NSF
$pFEDLIFESCI_{it-3}$	Life science federal funding (%)	987	10.55	23.67	0	1	NSF
$pFEDAGSCI_{it-3}$	Agricultural science federal funding (%)	987	7.27	15.18	0	13.29	NSF
$pINDFUND_{it-3}$	University R&D funding from industry (%)	987	8.70	10.266	0	47.91	NSF
TTOSIZE	Number of professional technology transfer staff[b]	987	3.00	4.57	0	60.2	AUTM
INCUBUTOR	Incubator presence (1 = yes)	987	.475	.499	0	1	SURVEY
$PATENTS_{it-1}$	Number of patents disclosed	987	14.97	33.079	0	437	USPTO
PUBLIC	Private university status (1 = yes)	987	.655	.460	0	1	TheCenter[c]
LANDGRANT	Presence of Land-Grant infrastructure (1 = yes)	987	.305	.460	0	1	TheCenter
MEDSCH	Presence of medical school (1 = yes)	987	.595	.533	0	1	TheCenter
$ENDOW_{it-3}$	Endowment base (US$ 000)	987	3963.54	449.36	0	14255996	TheCenter
REGION	Milken regional knowledge index (1–100 rating index)	987	53.92	23.29	23.5	92.3	MILKEN

[a] Financial resource data regarding U.S. universities can be accessed on National Science Foundation Website. Webmail address is http://webcaspar.nsf.gov.
[b] This figure represents the amount of Professional Full Time Equivalents (FTE's) dedicated to university technology transfer. This figure does not incorporate support staff employees in TTO office.
[c] *TheCenter Institute for university performance* produces the annual The Top American Research Universities report a project established to Measure University Performance in the U.S. Access to these tables or related information can be obtained on its Web site [http://thecenter.ufl.edu].

Table 4
Random effects negative binomial estimate of university spinoff production

Variables	Definition	Base model (model 1)	Knowledge accumulation effect (model 2)	Continuous learning effect (model 3)
$FACQUAL_{it-3}$	Faculty quality rating index of S&E	.3325796** (1135976)	.2405277* (.1091178)	.3214297** (.1034135)
$POSTDOC_{it-3}$	Number of postdoctoral appointees	−.0002507 (0001743)	−.0002686† (.0000158)	−.0002304 (.0001564)
$FACULTY_{it-3}$	Number of faculty	.0000993 (.000086)	.0001179 (.0000811)	.0001407* (.0000803)
$SEFED_{it-3}$	Total S&E federal funding	.2907211** (.89504)	.3052208*** (.0853802)	.2827959*** (.0831484)
$pENVCOMPSCI_{it-3}$	Computer science (%)	1.388098* (.5716385)	1.245468* (.5286441)	1.191703* (.5113065)
$pFEDCHEM_{it-3}$	Chemistry (%)	3.268202* (1.327096)	2.363714† (1.274508)	3.261967** (1.219958)
$pFEDENG_{it-3}$	Engineering (%)	.1079721 (.3756824)	.024651 (.3537687)	.0618166 (.3433258)
$pFEDCOMPSCI_{it-3}$	Environmental science (%)	.0672428 (.3730977)	.0276519 (.3499305)	.0510358 (.3389335)
$pFEDLIFESCI_{it-3}$	Life science federal funding (%)	.7717292† (.4040494)	.7294177† (.3820194)	.7301209* (.3695232)
$pFEDAGSCI_{it-3}$	Agricultural science (%)	.7290842 (.5101644)	.5467985 (.4804191)	.6888746 (.4646281)
$pINDFUND_{it-3}$	University funding from industry (%)	1.785518* (.834563)	1.50409† (.8354169)	1.644017* (.8025559)
$TTOSIZE$	Size of TTO	.0258304** (.0096131)	.0198746* (.0095109)	.0206143* (.0097511)
$INCUBUTOR$	Incubator presence	−.1581492 (.1117384)	−.1630058 (.1042326)	−.1487269 (.0999844)
$PATENTS_{it-1}$	Number of patents disclosed	.0033891** (.0013051)	.0029899* (.0012658)	.0006611 (.0015497)
$PUBLIC$	University status	.1091975 (.1472222)	.0676336 (.1377123)	.0649613 (.1330223)
$LANDGRANT$	Land-Grant infrastructure	−.1916402 (.1623191)	−.2622362† (.1516101)	−.2042223 (.1444047)
$MEDSCH$	Presence of medical school	−.1604942 (.1339835)	−.1950619 (.1253815)	−.1632339 (.1194034)
$ENDOW_{it-3}$	Endowment base	.3863908 (.5431044)	.0627324 (.0403892)	.036955 (.0405394)
$REGION$	Regional knowledge infrastructure index	.0007408 (.0038055)	−.0015452 (.0036088)	.0001299 (.003415)
$BEFORE_i$			.0195708*** (.0044676)	
G_{t-1}				.0215313** (.0066522)
Constant		−4.664743*** (1.078804)	−4.412585*** (1.032753)	−4.344877*** (1.006388)
Log likelihood		−1492.5276	−1483.7204	−1487.8589

Number of observations, 987; number of universities, 141. Standard errors in parenthesis.
† $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

5. Discussion

Recent research underscores the importance of universities in contributing to local economic development, leading edge research, high value jobs and innovation (Etzkowitz, 2002). Unfortunately, for many institutions, efforts to make universities more entrepreneurial have not had sufficient impact. In fact, recent findings in Europe (Jones-Evans et al., 1999; Wright et al., 2003) suggest that many universities are not experiencing a significant increase in spinoff behavior. As a consequence, many universities today are looking to improve their strategies for dealing with the vestiges of academic entrepreneurship.

From an academic standpoint, the reasons why rates of spinoff activity differ among universities have motivated economists and management scientists to study this important topic of recent. However, little is still known about the relative influence of university resource endowments in spinoff behavior. Therefore, using panel data from 1980 to 2001, we address this gap by developing a theoretical and econometric model to understand why some U.S. universities are more successful than others at generating spinoff companies. This longitudal approach allowed us to resolve the endogeneity issue that otherwise plagues cross-sectional technology transfer analyses.

A central finding of our research confirms the notion that each university, as a function of its history and past success, has different resource stocks available and these resource combinations are shown to be a relevant factor in explaining inter-university variation in spinoff activity. These findings support a path dependency argument that current choices of technologies, products and operation are heavily influenced, probably even constrained, by the cumulative effect of previous development (Arthur, 1989). Thus, public policy and university heads would be advised to intensify their activities to implement educational, research and resource programs to enable a culture of academic entrepreneurship to emerge within universities (Lüthje and Franke, 2003). Furthermore, the image of academic entrepreneurship as a career path for academics to pursue should be enhanced through developing incentives for academics to participate in entrepreneurial process.

Our second finding relates to the impact of science and engineering faculty quality on university spinoff activity. The presence of star scientists and engineers affect university spinoff activity as they have leading-edge knowledge with critical expertise and ability to create radical innovations (Schumpeter, 1950) conducive for commercial exploitation. Consistent with the work of Powers and McDougall (2005) and DiGregorio and Shane (2003), this result highlights the critical importance of investing, recruiting and retaining top ranked science and engineering faculty. However, it is worth noting, the number of faculty and postdoctoral staff aligned to an institution is incidental to spinoff production. These findings reinforce empirical work from Van Looy et al. (2004) that highlight the mutual reinforcing nature of faculty quality and entrepreneurial activity of universities.

A third finding of our study shows that the size and nature of financial resources allocated to universities influence academic entrepreneurship. First, we examined the ratio of industrial support to total research support in an attempt to capture the applied nature of research of universities and found a significant positive effect with this variable. Therefore, our result suggests that a greater proportion of industry-level funding is associated with higher levels of technology transfer. From a policy perspective, this suggests pursuing greater industry–university collaborations generate beneficial effects for technology transfer. Furthermore, our results also reveal that the size of federal science and engineering funding with a particular orientation on life science, computer science and chemistry disciplines show positive and statistically significant results. This finding supports the view those opportunities for technology commercialization and the propensity of faculty members to engage in technology transfer vary substantially across fields (Shane, 2004a; Siegel and Phan, 2005). This finding holds implications for policy makers seeking a return on investment from R&D expenditure inputs.

A fourth finding of our study also provides convincing evidence that the magnitude of resources invested in TTO personnel increases spinoff activity. In each regression specification model, our findings show results significantly different from zero. Given the complex and time-intensive job of identifying, sourcing and exploiting university technologies for commercial exploitation, this finding highlights the greater the size of the TTO offices, the greater the likelihood of the university to produce spinoffs.

These results are interesting because they clearly confirm the relevant role of tangible and intangible resources in accounting for university spinoff activity. In summary, these findings provide evidence that the organizational characteristics of universities play a significant role in the entrepreneurial behavior of academics. These findings suggest that in order for policy makers to encourage academic entrepreneurship a comprehensive systems approach to the identification, protection and commercialization of university intellectual property needs to be undertaken (Arrow, 1962). In particular, we argue (1) the need for the development of a commercially supportive culture to emerge within universities to enable academic entrepreneurship to flourish; (2) the need for active partnership and financial support with industry and government funding agencies; (3) the recruitment and development of science and engineering academic stars and (4) the development of a commercial infrastructure to enable the valorization of academic research to occur.

However, it also worth noting that while our research has found that spinoff activity is positively related to knowledge accumulation dynamics and learning effects, a limitation of our study is that it does not identify the university levels at which learning dynamic effects operate. Therefore, studies that can augment our current research findings with more fine-grained methods (Birley and Gartner, 2002) in the form of qualitative research may provide insights into where learning effects occur and the nature and processes they go through to influence start-up activity.

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