Delineating the anatomy of an entrepreneurial university: the Massachusetts Institute of Technology experience

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In many universities, heads, administrators and faculty seek to increase the propensity to engage in commercialization of research activity through the spinoff of new companies. The highly complex mechanism of spinoff generation is typically considered the result of either the characteristics of individuals, organizational policies and structures, organizational culture, or the external environment. Explanations of spinoff activity have in the main focused on only one of these dimensions at a time. In this paper we integrate these four dimensions of academic entrepreneurship to develop a more systemic understanding of spinoff activity at the university level. Using the case of Massachusetts Institute of Technology (MIT), a top spinoff generator in the United States, a systemic analysis is presented. We identify the inter-related factors that have contributed to successful academic entrepreneurship in MIT. We argue that MIT's success is based on the science and engineering resource base at MIT; the quality of research faculty; supporting organizational mechanisms and policies such as MIT's Technology Licensing Office; and the culture within MIT faculty that encourages entrepreneurship. However, to understand why MIT has developed these resources and organizational mechanisms, it is necessary to understand the historical context and emergence of MIT, and in particular the historical mission of the university, the role of key individuals and university leaders in supporting this mission, and the impact of past success at commercialization activity. Finally, we suggest that MIT's success needs to be understood in the context of the local regional environment. We argue that university administrators and academics can learn from the case of MIT, but that efforts at transposing or replicating single elements of MIT's model may only have limited success, given the inter-related nature of the drivers of spinoff activity.

1. Introduction

The increasing challenge of competing in a global economic context is forcing regions to reconsider and often revise their approach to economic development. With knowledge now the fundamental basis of competitive advantage, regional economic development agencies are looking for ways to create and develop new innovative, technology-based start-ups. One of the key technology transfer mechanisms that has attracted attention in recent years is the emergence of university spinoffs. University spinoffs are a highly successful sub-set of all start-up firms because they generate jobs for highly skilled graduates and demonstrate strong economic effects for regional communities (Shane, 2004a; Rothaermel and Thursby, 2005). With knowledge and innovation recognized as a third production factor beside labor and capital, universities are increasingly looking for ways to play a greater role in regional economic development. Therefore, university heads and administrators seek explanations of the dynamic factors that contribute to the emergence of a successful university. They want to know how to increase spinoff activity. In this paper, we aim to provide answers to this question.[1]

In the academic literature, there are many models that seek to explain spinoff activity from institutions of higher education. Most studies have neither been effective in explaining spinoff behavior nor particularly suited to the needs of institutional officials who seek to stimulate spinoff activity on campus (Shane, 2004a; Lockett & Wright, 2005). This has been the result of the tendency of existing explanations to downplay, if not entirely overlook, the role that the institution plays in determining start-up activity. Additionally, it has been argued that most so-called theories are actually atheoretical in nature (Nicolaou and Birley, 2003). That is, they suggest relationships between events in the form of a model without specifying a consistent form of explanation that accounts for those relationships.

In this paper, we use prior research to identify the drivers of spinoff activity. We identify four perspectives that dominate the extant literature on spinoff activity. We use these perspectives to inform a study of a single university, Massachusetts Institute of Technology (MIT), which has been highly successful at generating large numbers of spinoffs. We present factors that we believe explain the success of MIT. We explain how events within an institution can shape the process of spinoff behavior within that institution, and how external forces impacted on the institute's orientation. As such, we suggest how institutions can alter their organizational practices and technology initiatives and policies to spinout more technology-based firms.

2. Background literature – theoretical perspectives

In seeking to explain spinoff activity, a number of perspectives have been adopted. These include studies that explain spinoff activity in terms of the individuals who engage in such behavior; those that emphasize the organizational characteristics and resource endowments of the university; those that argue that social norms and institutional behavior determine spinoff activity; and finally those that argue that the wider social and economic context enables spinoff activity. We now briefly outline each of these perspectives.

In the university entrepreneurship literature, a number of studies have used 'personal characteristic' models to explain spinoff departure by academics. These studies tend to emphasize the impact of individual abilities and dispositions on the entrepreneurial behavior of academics. Studies such as those by Shane (2004a) point to the importance of entrepreneurial attributes in shaping the individual's behavior toward establishing a firm, while those by Roberts (1991) stress the role that personality, motivation, and disposition play in influencing academic entrepreneurship. However framed, this view of academic entrepreneurship shares a common theme, namely that spinoff behavior is a reflection of individual actions and therefore are largely due to the ability or willingness of the individual to engage successfully in entrepreneurial behavior. While this view may partially explain the spinoff phenomenon, it represents only a partial explanation as it ignores the impact of the environment on individual behavior.

A second perspective is that of social scientists. Organizational theories of university spinoff behavior are generally concerned with the impact of environmental forces on academic entrepreneurship. Such researchers focus their attention on the structural characteristics and resource endowments of the university. Specifically, researchers have sought to establish links between spinoff activity and (i) the level of research funding (Powers and McDougall, 2005); (ii) the quality of the researchers and the nature of the research within the university (O'shea et al., 2005); (iii) the

strategic orientation adopted by the institution (Davenport et al., 2002; Moray and Clarysse, 2005; Siegel et al., 2003a); and (iv) the nature and structure of the commercial infrastructure of the university (Debackere, 2000; Debackere and Veugelers, 2005; Feldman et al., 2002; Lockett and Wright, 2005).

A third perspective to the study of spinoff activity has as its central proposition that university spinoff activity is a reflection of social norms and institutional behavior. This research, which we refer to as the 'institutional' stream of research, argues that universities that have cultures that support commercialization activity will have higher levels of commercialization and higher rates of spinoff activity. Similarly, university environments that do not encourage entrepreneurship will have less spinoff activity. For example, Louis et al. (1989) found that local group norms were important in predicting active involvement in commercialization. They argued that this might be due to self-selection, which produces behavioral consensus, and behavioral socialization, where individuals are influenced by the behavior of their immediate peers. In essence, the central point of these authors has been that university start-up activity is as much, if not more, a reflection of institutional behavior, as it is of individuals within an institution.

A fourth perspective to the study of spinoff activity explores the impact of the wider social, economic, and organizational forces on academics within institutions of higher education. Florida and Kenney (1988) highlight the central role that venture capital availability plays in encouraging the formation of high-technology firms in regions as they provide essential risk capital and operating assistance to new firms. Saxenian (1994) argues that spinoff activity is more likely to occur in high-technology clusters. She suggests that this is because of the easier access to critical expertise, networks, and knowledge. More generally, Shane (2004b) argues that a significant impetus to increased spinoff activity in the United States was the enactment of the Bayh–Dole Act. This act assigned inventions to academic institutions rather than individual inventors.

Collectively, these four perspectives have provided an increased understanding of, and knowledge about, the highly complex mechanism of spinoff generation. However, the four perspectives have largely remained distinct from one another. It is our belief that these different perspectives would, if brought together, provide a much more thorough understanding of the spinoff phenomenon.[2] In this paper our objective is to explore the synergistic effects of these factors in understanding spinoff activity.

3. Research method

3.1. Study approach

In this paper we will consider a very successful university to explore the degree to which these factors are present or absent. Rather than focusing on a single attribute across several units, we will concentrate on a single entity and assess the ways in which many attributes operating both independently and through interaction appear to influence an outcome, in the form of spinoffs.

Therefore, in this paper, we utilize a 'systems thinking' perspective to direct an inductive study of MIT. We believe that such an approach is appropriate to the study of MIT, given the interrelated nature of the phenomenon of spinoff activity. A systems thinking approach allows us to integrate prior research on spinoff activity. This means that instead of isolating smaller and smaller parts of the system being studied, systems thinking works by expanding its view to take into account larger and larger numbers of interactions as the issue is being explored.

To accomplish our task, we utilized multiple sources of evidence to investigate MIT's spinoff activity. These data-collection efforts produced a combination of quantitative and qualitative data, allowing triangulation (Jick, 1979). Data was collected using in-depth semi-structured interviews with Technology Licensing Office (TLO) officiers, venture capitalist investors, university leaders, and academic entrepreneurs within MIT. Triangulation was also aided by the collection of archival data including university-level information provided by the MIT website, published books on MIT, and archival documents. We also utilized a number of quantitative databank sources for our analysis including the National Science Foundation (NSF), Association of University Technology Managers (AUTM), National Research Council (NRC), US News & World Report, and the Center for University Performance Research.

4. MIT

MIT is a world-class educational institution. Teaching and research, with relevance to the practical world as a guiding principle, is its primary purpose. MIT is independent, coeducational,

and privately endowed. Beginning as a land grant university (cf., www.higher-ed.org/resources/morrill_acts.htm), MIT has a long history of partnership with the social and economic development of the state of Massachusetts. The university employs slightly over 900 faculty members (Table 1) and enrolls approximately 4,300 undergraduates and 5,950 graduate and professional students.

The university is comprehensive in scope. Degrees are awarded in five schools. These units encompass 34 academic departments, divisions, and degree-granting programs, as well as numerous interdisciplinary centers, laboratories, and programs whose work cuts across traditional departmental boundaries. The Institute is international in orientation in many ways, including the fact that a large proportion of MIT students come from outside of the United States. MIT has been very successful in fostering entrepreneurial approaches to technology transfer. MIT has one of the oldest and most successful technology transfer functions in the United States. According to the AUTM survey, MIT achieved the highest ranking for all universities in the United States between 1980 and 2001 (Figure 1) by generating a total of 283 spinoffs including 183 in the 1995–2001 period (Figure 2). University of California and Stanford were ranked second and third producing 122 and 82 spinoff companies within the 1995–2001 period, respectively. MIT maintained a Top 5 ranking out of 141 universities for all seven time periods of observation and generated an average production rate of 18.85 spinoffs per year.

Table 1. MIT faculty and student numbers.

MIT Profile	No.	%
Total faculty	923	
Of which science and engineering	588	64
Total students	9,972	
Undergraduate students	4,300	43
Of which engineering	2,011	47
Graduate students	5,672	57
of which engineering	2,504	44

5. Data analysis – attributes of a successful university

We present our analysis of MIT, focusing on a number of factors that emerged from the literature and could potentially underlie MIT's success. These factors reflect the resource endowments of MIT in terms of its science and engineering research funding (Factor 1); the flow of industry funds for research (Factor 2); the quality of the academic staff (Factor 3); organizational characteristics such as the TLO practices and policies (Factor 4); the mission of the university (Factor 5); the culture that has developed among MIT faculty (Factor 6); the history and tradition of MIT (Factor 7); and the external geographical context in which MIT operates (Factor 8).

5.1. Factor 1: science and engineering resource base

An important, and necessary, aspect of MIT's ability to create university spinoffs is its ability to attract large financial resources to fund leading-edge science and engineering research. As a biotechnology technology transfer employee explains:

> '. . . *having access to strong financial R&D funds has enabled us to develop a wealth of good*

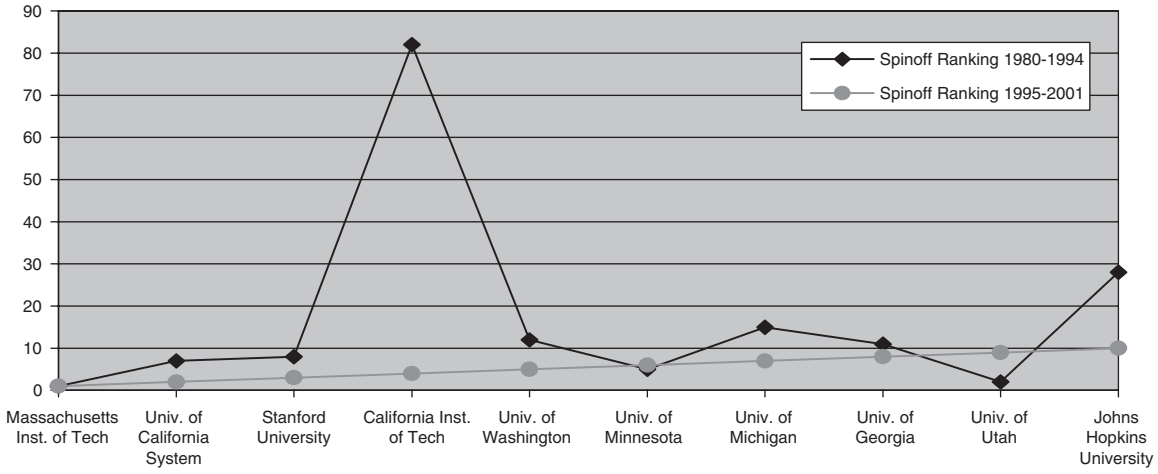

Figure 1. Spinoff rankings of US universities FY 1980–1994 and 1995–2001.

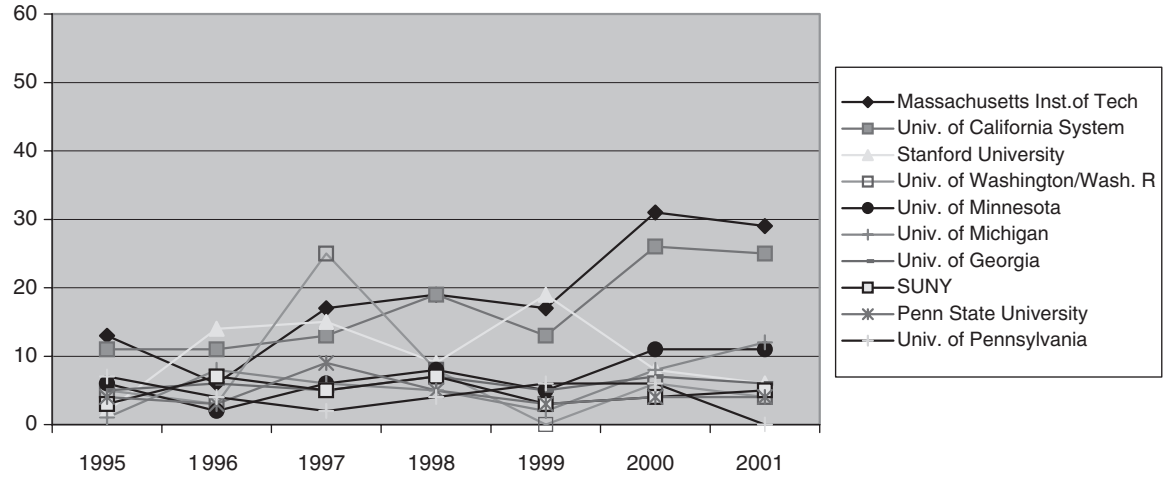

Figure 2. Top-ranked spinoff universities in the US FY 1995–2001 ($n = 180$).

> *technology - technology that is world class and that, while often embryonic and basic, often has great commercial value*.'

MIT has a strong record as a research-intensive institution. In the National Science Foundation FY 2001 survey of academic research and development, MIT reported research expenditures of $435.5 million,[3] ranking it 11th among all US universities and eighth among private universities. In terms of federal funding research revenues, MIT was ranked ninth in 2001 (Table 2).

5.2. *Factor 2: industry funding of research*

In addition to a large absolute amount of funding, it appears that the source of funding may have been important to MIT. MIT has been successful in attracting large amounts of industry funding for research, ranking third among US universities in 2001 (Table 3). Industry-related research has played a strong role in the commercialization of research output. MIT's interest in attracting industry funding for research reflects its belief that such funding can improve education. According to Charles Vest, outgoing President of MIT:

> '*MIT has worked hard during the last few years to develop strong and appropriate research relations with private industry for three reasons: to improve our education; to diversify our sources of financial support; and to create new pathways for contributing to the common good.*'(Vest, 2004).

Industry research funding is not confined to applied research projects but also funds basic research. For example, Dr. Vest commented as follows: 'partnerships at MIT involve direct scientific collaboration with companies such as Amgen and Merck. These partnerships involve no federal component. They support mutually agreed-upon basic research problems at the cutting edge of

Table 2. Federal funding for US universities FY 2001.

Rank	University	2001 federal funding
1	University of California System	1,530,117
2	Johns Hopkins University	879,741
3	University of Washington/Wash. R	435,103
4	University of Michigan	396,117
5	Stanford University	384,468
6	University of Pennsylvania	351,996
7	Columbia	317,928
8	University of Colorado	308,643
9	**Massachusetts Institute of Technology**	**304,319**
10	University of Wisconsin – Madison	304,009

Source: NSF: N:270.

Table 3. Industry research funding allocated to US universities.

Rank	University	2001 industry funding
1	University of California System	175,958
2	Duke University	104,063
3	**Massachusetts Inst. of Tech.**	**97,256**
4	Penn State University	67,658
5	Georgia Institute of Technology	59,691
6	Ohio State University	54,736
7	University of Washington/Wash. R	43,312
8	University of Maryland, Baltimore	41,226
9	North Carolina State University	37,858
10	University of Florida	36,417

Source: NSF 2001.

Table 4. Faculty quality ranking.

Rank	University	Index score
1	**Massachusetts Institute of Technology**	**4.7**
2	University of California-Berkeley	4.62
3	Harvard University	4.6
4	California Institute of Technology	4.59
5	Stanford University	4.55
6	University of Chicago	4.43
7	Princeton University	4.35
8	Yale University	4.28
9	Cornell University, All Campuses	4.15
10	Columbia University in the City of New York	4.08

Source: National Research Council, 1995, N = 270.

modern biology and biotechnology, and encourage intellectual synergy and sustained dialogue among company and academic scientists.'

5.3. Factor 3: quality of faculty

A key ingredient for successful technology transfer at MIT is its distinguished faculty, the quality of its faculty, and their ability to generate radical innovation conducive to commercialization. MIT's bequest sets out the vision that the university would be 'a university of high degree.' As such, it has sought to attract the most accomplished faculty and students with the greatest potential. The National Research Council (NRC) ranking of faculty quality in science and engineering in US universities ranks MIT first with an index value of 4.7 out 5 (Table 4).

A number of graduate departments within Science and Engineering are also highly ranked by the US News & World Report. MIT graduate programs appear in the top 10 in all but two fields ranked by US News & World Report. For example, in Engineering, MIT ranks first overall, with no sub-specialty ranked lower than sixth. In the chemical sciences, MIT ranks first overall, and is joint-second place in computer science and biology (See Appendix A).

MIT has a system that is built around steeples of expertise, whereby recruiting and retaining a 'critical mass' of faculty members in a selected niche or sub-discipline is undertaken. Furthermore, the teaching and research focus of MIT is in domains that are conducive to commercialization. MIT is dominated by science and engineering academics representing over 64% of all academics. The graduate population is dominated by engineers (53% of students), with the physical and life sciences scoring the next highest.

Throughout the years, MIT faculty have been at the forefront of research in many fields, 'MIT history is replete with radical thinkers . . . . . who have truly founded or transformed major fields of scholarship or technology' (Vest, 2004). MIT faculty members have pioneered some of the foundations of brain research, and their work continues to contribute broad insights in the fields of artificial intelligence, cognitive science, linguistics, computational and systems neuroscience, and molecular and genetic neuroscience. For example, MIT's Hans-Lukas Teuber established the field of neuropsychology in the 1960s by studying patients with brain lesions, and later founded the MIT Department of Psychology. Professor Eric Lander and other faculty members have played critical roles in mapping the human genome. This leading-edge work in emerging technological fields provided the basis for a number of spinoffs.

5.4. Factor 4: organizational characteristics: TLO, entrepreneurship programmes, and inter-disciplinary research

A number of organizational structures and practices facilitate commercialization of research. These include the TLO, the Sloan School Entrepreneurship Center, the Deshpande Center for Technological Innovation, Entrepreneurship Development Programs, and inter-disciplinary Research Centers.

5.4.1 TLO

MIT has one of the more active and successful technology transfer programs in the United States. The MIT TLO was established in 1945 (until 1985, it was known as the Patent, Copyright and Licensing Office), many years before most universities were encouraged to take similar steps by the Bayh–Dole Act. The TLO office plays a very proactive role in technology transfer activities. Rather than waiting for a technology pull, reacting to requests for licenses from interested companies, the TLO encourages faculty to disclose inventions promptly, and then quickly and carefully evaluates the market value of inventions, and obtains protection of intellectual property. It also meets with venture capitalists to discuss new technologies and ongoing research at the Institute that may be appropriate for a start-up venture. Promoting start-ups and taking equity in lieu of royalties began at MIT at a time when such an approach was unheard of in many of MIT's peer institutions.

The TLO is closely attuned to the economic development mission of MIT and the entrepreneurial culture of the institution. In keeping with the university's supportive approach to faculty entrepreneurship, policies supportive of commercialization have evolved. A number of basic principles guide MIT's conflict of interest policies for technology transfer, and these basic principles also apply to start-up activities. MIT is acknowledged to have one of the strictest policies on managing these and other conflicts of interest arising from its licenses and collaborations with industry. However, according to the TLO Director, 'these clear policies, well thought out and consistently applied, are designed to facilitate start-ups. The simplicity, the strictness and no-exceptions rules for keeping MIT and its start-ups separate actually help keep things moving, because negotiations do not get bogged down while committees ponder over exceptions and risks.'

The policy is as follows (Ittelson and Nelsen, 2002):

- Technology transfer and entrepreneurial activities are by-products (not the purpose) of the academic mission of education, basic research, and dissemination of knowledge.
- Technology transfer activities must not deflect or distort this core mission. When conflicts of mission arise, the academic activity always takes precedence.
- There must be no incubation of the company within MIT once it has been formed. Faculty members may consult and be board members, but may not be line officers of the company.
- MIT sometimes shares risks in start-up companies by taking shares of stock in start-up companies in partial lieu of royalties (most times they do both).
- Faculty are required to report all outside consulting activities with start-ups.
- Faculty members may not negotiate terms of the license with MIT. No sponsored research will be accepted from the company if the faculty founder holds equity in the start-up.
- No confidentiality of MIT research results is permitted; everything should be published. Only patents and copyrights can be licensed (no exclusive licenses to 'knowhow' or trade secrets).
- Before starting up a company, the faculty founders must sign a 'conflict avoidance statement,' promising not to accept research support from the company, not to suppress for the company's benefit the dissemination of research results developed at MIT, and not to use students on any company projects (that is, current students may not be employed by the start-up company).
- All the financial dealings between the new company and MIT are kept at arms length. MIT will not invest in early funding rounds and takes no board seat. The MIT treasurer, not the TLO, manages any equity received by the Institute from the start-up at its inception. Importantly, the company receives no rights in future research in the field of the license.
- MIT provides exclusive licenses to academic entrepreneurs (and companies) willing to step forward and start a company – knowing that if it succeeds in the development, the exclusive license will protect it from having its product copied by those who 'weren't willing to take that risk.'
- In terms of royalty distribution formulas for inventor founders of technology once patent costs are paid, and 15% of royalties are paid to the TLO, the one-third of the remaining will go to inventors, and the rest will be divided between departments, interdisciplinary centers, and the MIT General Fund

5.4.2 Entrepreneurship development programs

MIT has supplemented a rigorous engineering curriculum with formal and experiential education in entrepreneurship, drawing on the local alumni base and faculty role models. This program, and perhaps more importantly the underlying culture of the institution, has a strong influence on students and graduates. Supporting entrepreneurial activity has long been a very important part of the culture of MIT, but its role and importance have accelerated dramatically. This aspect of MIT's culture is fostered in a number of ways. One of the most visible of the new programs is MIT's Deshpande Center for Technological Innovation. Founded with a $20 million grant from Desh and Jaishree Deshpande, the center identifies MIT researchers with promising ideas that can be developed more rapidly and effectively with a modest infusion of grant money for ongoing research and expert advice to guide the spin off. From inception in 2002 to 2004, the center has funded 51 projects with more than $6 million in grants. Nine projects have developed into independently funded companies, having collectively raised more than $40 million in financing from top-tier venture capitalists. One of the Deshpande Center's major objectives is outreach to industry in order to bring a market perspective

to the work of university-based researchers as early in the innovation process as is practicable.

The Center for Entrepreneurship, located at the Sloan School of Management, aims to engage students and faculty from throughout the Institute; to provide research and educational programs in electronic commerce and in new product and venture formation; and to offer a variety of programs for mentoring students and alumni who are interested in starting new businesses. According to the Director of the MIT Entrepreneurship Center, 'MIT scientists, engineers, and managers believe that it is not enough merely to invent a new product, concept or technology. The measure of success is global commercialization and widespread acceptance of their innovations.' According to the Director, MIT is not satisfied with the production of knowledge, patents, and degrees. MIT wants these things to be applied to commercial use, and it tries to train its own staff and students to become competent enough to make high-tech ventures successful.

5.4.3 Interdisciplinary research centers

MIT has a long history of securing funding for interdisciplinary studies, both within MIT and with associated institutes. Internally, MIT houses over 60 research centers. For example, the Research Laboratory of Electronics, founded in 1946, is MIT's oldest and largest interdisciplinary research laboratory. Off-campus, the MIT Lincoln Laboratory has been a pioneer in advanced electronics for national security since 1951. The Whitehead Institute for Biomedical Research, an independent research institute whose faculty members are jointly appointed to the MIT Biology Department, has been rated among the top three biomedical research institutes in the world. The Broad Institute, the largest public sequencing center in the world, is considered a leading laboratory in the Human Genome Project consortium. Highly successful spinoffs such as Momenta and Alnylam had their origins in such research centers.

5.5. *Factor 5: university mission*

The mission of MIT is to 'advance knowledge and educate students in science, technology, and other areas of scholarship that will best serve the nation and the world in the 21st century'.

According to the MIT Charter:

> '*... by the name of Massachusetts Institute of Technology, for the purpose of instituting and maintaining a society of arts, a museum of arts, and a school of industrial science, and aiding generally, by suitable means, the advancement, development and practical application of science in connection with arts, agriculture, manufactures, and commerce*.'

Since its foundation as a public land grant institution, MIT has earned an international reputation for faculty commitment to local economic development. This stems from MIT's founder William Barton Rogers' concept for a new kind of science-based technological university. He conceived a university with links to industry so that the research university's 'linear model' could be combined with the land grant university's 'reverse linear model' predicated upon deriving research goals from societal needs. Rogers stressed the pragmatic and practicable (Etzkowitz, 2002). He believed that professional competence is best fostered by coupling teaching and research and by focusing attention on real-world problems. To this end, he pioneered the development of the teaching laboratory. This legacy has left an indomitable mark on the university. In addition, Rogers tirelessly worked to link the university's efforts in research and education to the interests of business and government (Etzkowitz, 2002). He was continually concerned that there would be jobs in the region for MIT graduates. According to MIT's Director of Technology Transfer:

> '*We were initially set up as a land grant university with the mission geared towards economic development so we had less of a philosophical issue, deciding whether technology transfer was something we should engage in, in comparison to other universities*.'

A senior faculty member at the Sloan School supports this view. He argued that the original mission of the university provided the foundation stone for the entrepreneurial spirit to flourish at MIT from the outset.

Commercialization is considered an automatic and natural consequence of research activity. According to the former Operating Director of the Deshpande Center 'the university's mission is to teach and to conduct novel research. Commercialization of technology is just the icing on the cake.' Outgoing MIT President Vest also commented that 'when faculty act as entrepreneurs, our conflict-of-interest policies have two basic objectives – to ensure openness of information flow in our classrooms and laboratories, and to keep research agendas in our laboratories from

being improperly affected by the personal financial interests of faculty or staff.' The thrust of the mission and the policies and practices that have been adopted within MIT are clearly oriented toward enabling would-be entrepreneurs. This shift in philosophy has been enhanced further over the last decade and is also associated with the entrepreneurial development programs and funding opportunities of the MIT Entrepreneurship Center and the Despande Center for Technological Innovation.

5.6. Factor 6: MIT faculty culture

On the surface, MIT's faculty culture appears to be quite traditional. Given the 'steeples of excellence' approach, MIT recruits the top candidates in those fields where it has built its academic focus. Expectations for continued academic achievement are high, and for the most part tenure and promotion are based solely on academic achievement and building an outstanding academic reputation among the national 'invisible college' of scholars. Outside activity, including working with companies or starting a company, are neutral factors. Tenure and academic promotions are granted on academic achievement.

However, there is another important aspect to MIT's academic culture. Faculty members are expected to support themselves and their research activities with relatively little help from the institution beyond start-up support for new faculty members. As such, the MIT culture rewards the 'academic entrepreneur.' As a result, there has been an open environment in which carrying out research with a company or a new venture is not considered in a negative light, provided it enhances the education of students and provides or contributes to opportunities to conduct important, nationally visible research.

There appears to be little 'either/or' attitude about business sponsorship of research versus government support:

> '*The Institute believes that its educational programme and effective teaching in all its aspects can flourish only when sustained by continuous, active participation of its faculty in research, enriched in many cases by interaction with industry, business, government, and other activities and institutions of our society. This interaction, including outside consulting service to, and research for, government and industry, is of greatest value when it contributes significantly to the public welfare, offers an opportunity for professional challenge and growth, or otherwise enhances the effectiveness of a faculty member's service to the Institute*.' (MIT, 2004).

What sets MIT apart from other intellectual centers is not that it contains extremely smart people with big ideas; but rather it is that there are so many smart people in the one part of the world tailor-made to take their ideas and turn them into something real – and often profitable. As one successful academic entrepreneur explains:

> '*Our faculty's commitment to deep, fundamental research and scholarship is matched by a desire to transfer new knowledge and technologies into the world in important and beneficial ways*.'

This view is shared by outgoing President Vest (2004), who stated the 'MIT environment is very supportive to start-up ventures. At MIT, industrial careers are respected (even in the biological sciences), and entrepreneurship is the goal of many on campus. Past successful MIT start-up ventures encourage faculty and students to take the plunge themselves and provide a group of very visible role models – a real cheerleading group.'

Although it is neither favored nor precluded, taking time off from an academic career to work in a company, owning a piece of a company, or developing your own inventions is not atypical of an MIT professor's career in the sciences and engineering. Continued and frequent examples of this activity provide strong and plentiful role models for both junior faculty and students. In past years, taking time off to work in a company generally did not happen until a faculty member received tenure. However, this pattern began to change in the late 1990s as non-tenured faculty are now considering this route as well. As the TLO Director commentated:

> '*There is very much a word of mouth culture among the faculty almost to a point if you haven't done one [a spinout] yet you start to wonder what is wrong with you. Also if you are young and impressionable, as are students, and you come and spend four years in this place your going to meet at least twenty people who have started [a company] so you come out thinking everyone has done it and that I can do it to. So simply an exposure to entrepreneurship raises your expectations*.'

According to a former staff member of the TLO office, there are a number of reasons that drive

the desire and motivation of MIT academics to engage in entrepreneurial activities. First, there is a quest for academics to validate their technology in the market place. Second, many academics see the game of business as interesting and stimulating. Finally, there is a desire for the accumulation of wealth. Different people balance these three motives differently. From our interviews with academic entrepreneurs, the quest for validation of their technology came out as the strongest motivating factor. For example, the founder of two highly successful biotechnology companies explains:

> '*I wanted to see my inventions making a difference in peoples lives and not just sitting idly on the research bench in the lab*.'

5.7. Factor 7: history and tradition

The orientation of MIT and the culture of its faculty partly reflect the historical emergence of MIT. A number of historical events and choices appear to have positively impacted on the emergence of MIT as a university that is highly prolific in spinoff activity.

First among these is the 'land grant' movement. MIT has a long and distinguished track record of involvement in, and commitment to, promoting economic development. Undoubtedly, the university's land grant heritage, with its emphasis on the importance of service and extension, played an important role in these activities. According to a former MIT President: 'the land grant movement invented a university that was committed to the economic and social development of its region. It created a university that took local needs and circumstances into account in developing its research and training programmes. The land grant academic model inspired a significant element of the development of MIT as a school committed to regional development of the Boston area in the mid-nineteenth century and New England in the mid-twentieth century' (Vest, 2004).

During the 1930s depression, President Karl Compton hypothesized that New England's research-intensive universities could substitute for the natural resources that the region largely lacked. He developed instances of firm formation by MIT professors into a model of university-based economic development that built upon the comparative advantage of New England, its concentration of research resources in its colleges and universities. This strategy of assisting firm formation based upon academic research originated early in the 20th century as part of a new thesis of science-based regional economic development set forth in the 1930s by a group of MIT administrators, and its tradition continues today.

The relatively narrow focus of MIT in terms of disciplines meant that this mission has continued to receive support from faculty. As the TLO Director explains:

> '*Part of the reason that the culture is different in contrast to Harvard, Yale or Princeton or even Stanford is that we are not a broad based university where the poets and historians would object to closer ties with industry. We are a much narrower focused university and therefore from a university governance viewpoint, there is less of a philosophical objection to dealing with industry . . . the vast majority of people at MIT are technical personnel*.'

The second historical event that was important to MIT was the expenditure by the US government on research. In the 1950s, as tensions increased between the United States and the Soviet Union, the federal government actively looked for new defense technologies, and encouraged the private sector to develop technologies and build devices that would help make the nation's military strong enough to secure dominant world leadership for the United States (Etzkowitz, 2002). In 1945, Dr. Vannevar Bush laid out in his report to President Truman a blueprint for the growth and development of America's scientific enterprise. In 'The Endless Frontier,' he proposed an intensive effort to advance technology in the service of the nation's foreign policy and welfare (Etzkowitz, 2002). Defense contracts for both research and development and procurement for national security purposes fueled the growth of communications, computing, and electronic industries in the 1950s and 1960s. MIT and the newly founded businesses spun out during the post-war years benefited from these trends.

Third, a number of individuals in MIT's history have played important roles in shaping MIT as an institute that supports commercialization activity. For example, Vannevar Bush's consulting and firm formation activities in the 1940s were influential, especially since Bush later rose in the administration ranks to vice-president and Dean of the Engineering School (Etzkowitz, 2002). Similarly, the MIT tradition of academics taking time out to work in industry reflects decisions as far back as the 1840s when William Barton

Table 5. Technopole index.

Rank	State		Index score
1	**Massachusetts**	**MA**	**84.90**
2	Colorado	CO	80.58
3	California	CA	80.37
4	Maryland	MD	77.86
5	Virginia	VA	73.33
6	Washington	WA	71.81
7	New Jersey	NJ	69.95
8	Connecticut	CT	68.58
9	Utah	UT	68.26
10	Minnesota	MN	65.87

Source: Milken Institute, 2002.

Rogers, MIT President, encouraged the culture of commercializing discoveries. As current MIT president Susan Hockfield explains:

> '*Rogers saw the need for a new kind of academic institution – one that could train students to put the advances of modern science to work for the betterment of humankind. It is this vision that set the course that the Institute has followed for nearly a century and a half.*'

Fourth, there has been a long history of developing ideas and commercializing research. There has been a continuous thread of powerful new ideas developed and commercialized at MIT. As Hiestand and Zellman (2004) commented: 'for over one hundred years, people have come here to Boston to learn what has been done in their field so far, stake a claim to an acre of the as-yet-undone, and begin tilling the hard ground.' For example, Philip Sharp helped launch the biotech revolution in the mid-1970s when he pioneered a method for rapidly reading the nucleotide sequences of DNA and RNA, work for which he later received the Nobel Prize. Sharp was later founder of Biogen, part of the first crop of biotech start-ups form MIT.

5.8. *Factor 8: MIT location: regional technopole of Boston and Cambridge*

MIT is located in a region that supports and acts as a 'virtual incubator' for entrepreneurial activity and new technology-based spinoffs. The Santa Monica-based Milken Institute recently dubbed Massachusetts as the state most likely to succeed 'in the technology-led information age' based on research development (R&D) initiatives, investment activity, and the quality of the workforce, among other factors (Table 5). Massachusetts has a higher percentage of its workforce in high-tech jobs than California does. As for why the greater Boston region gives rise to more innovation than others, one author said of Boston: 'the explanation is as simple as why you don't get tulip bulbs to grow in Russia. The soil is not there. . . . . You can wish it, but if you don't have the soil, the history, the educational system, and the assumptions people make about the way their careers will go, all you will do is wish' (Hiestand and Zellman, 2004).

As Shane (2004b) commented, when MIT students graduate and want to start new companies, Boston's venture capitalists provide funding and guidance, and introduce young scientists to experienced executives who can help them manage and nurture their promising start-ups. Additionally, there is a cluster of hospitals where researchers can conduct trials of new drugs, medical devices, and therapies. As the TLO Director explains:

> '*Although geographical location does not explain differences between MIT and Harvard, it does explain differences between MIT and other universities. People ask me whether MIT has an incubator and I say 'yes it's the city of Cambridge'. This is a geography experienced in entrepreneurship. It has got a lot of experienced executives. It now, although didn't have much ten years ago, has a lot of indigenous venture capital. There are accountants, real estate agents, etc . . . well used to dealing with start-ups.*'

6. Discussion

In this paper, we set out to identify the factors that determine spinoff activity in universities, exploring the synergistic effects of these factors. We studied the case of MIT, a leading university in terms of spinoff activity. We suggest that no one factor can adequately explain the success of MIT in terms of the commercialization of research and spinoff firms. Our data suggests that the following factors could be significant in explaining MIT's success.

- MIT's excellent research in a number of 'practical fields,' combined with a willingness to pursue interdisciplinary research, has been a strong driver in the creation of the knowledge that start-up companies have exploited.
- Over a long period of time, MIT has developed informal internal and external networks between government, industry, and academia.

These networks have increased and leveraged research funding at MIT and has allowed for the sharing of knowledge. This has in turn helped to stimulate high-tech entrepreneurship.

- MIT has a number of dedicated and experienced organizational structures such as its TLO and entrepreneurship programs. These resources are dedicated to promoting emerging technological opportunities within the biotech/ICT sectors and to training potential academic entrepreneurs to create and build successful start-ups.
- MIT has demonstrated a strong commitment to the exploitation of research. This commitment is supported by clear policies, that are consistently applied, that support and encourage start-up formation by academics.
- Within the TLO, MIT has a staff of technically trained, industrially experienced licensing officers. The staff in the TLO office appears to get a great deal of satisfaction from 'getting the deal done.'
- MIT's successful tradition and history at commercializing radical technologies (via start-ups) has created a 'success breeds success' start-up culture among academics and staff.
- Academics within MIT have positive attitudes to commercializing technology and starting companies.
- MIT has a long tradition of industrial and military funding, which has led to commercially oriented innovations.
- MIT is located in (and was instrumental in building) one of the leading high-tech clusters in the United States. This gives academics access to critical expertise and resources to spinout ventures.

7. MIT spinoff performance model

Our data suggest that there can be many drivers of spinoff activity (Figure 3), and that these factors collectively explain spinoff activity. Our model suggests that four attributes of the university can be important in supporting and encouraging spinoff activity. The first of these is the science and engineering resource base of the university. We suggest that it is not only the absolute level of research funding that determines spinoff activity but two other factors are also important. First, the source of research funding

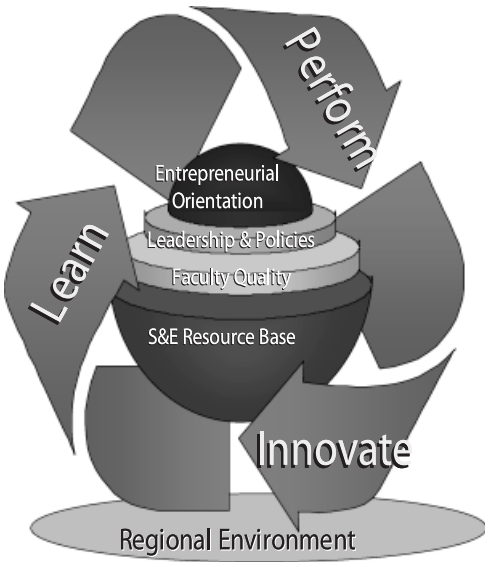

Figure 3. Spinoff performance model.

matters. Connections between the university and industry and government-sponsored research programs can provide the university with both increased research funds and access to market-related knowledge. Second, the areas of research expertise that develop within the university matter. Some areas, in particular those in the more rapidly advancing fields of Engineering and Science, are more likely to be associated with new technologies and knowledge with commercial potential.

A second driver of spinoff activity is the quality or excellence of the staff's research activity. This is facilitated by attracting leading academics and top-class students. Expertise should be concentrated into areas that the university believes will produce the greatest payoffs.

The third driver of spinoff activity, what we refer to as Leadership and Supporting Policies, is a commitment within the university to commercialization and spinoff activity. Specifically, the case of MIT suggests that policies should support the commercialization of academic research, although this should not be at the expense of a commitment to the highest standards and performance on traditional measures of academic success. The case of MIT suggests that these objectives can be achieved simultaneously. Where academics wish to engage in commercialization activity, the institution should support such efforts through measures such as the provision of training and advice in entrepreneurship and a well-run market-focused TLO.

The fourth driver of spinoff activity is the culture within the university – what we refer to

as an Entrepreneurial Orientation. Where academics experience a culture that champions commercialization activity and when they experience direct exposure to role models of those that have successfully commercialized research, they are more likely to engage in such activity.

The emergence of these drivers of spinoff activity reflects a path-dependent process, with the history of the institution and the context of the development of the university's mission playing an important role. Judging from what we see in this example, and in our other research (O'Shea et al., 2005) there is a systemic process, whereby learning effects from previous success partially determine current spinoff activity (i.e. learn, innovate, and perform). For example, in the case of MIT, historical factors such as the original mission of the university, early commitments by key individuals to commercialization activity, and success at commercialization and spinoff activity all played a key role in the creation of the resource base and culture that currently drives spinoff activity at MIT.

The final driver of spinoff activity is the regional context of the university. Spinoff activity requires support from innovative customers and access to resources, including finance. Spinoff activity is more likely to occur where the local environment outside the university is supportive of entrepreneurial behavior.

8. Conclusion

MIT is an extraordinarily successful research university that has also nurtured a long-standing mission of service to its state and national interests, while at the same time creating a very entrepreneurial culture and some novel approaches to technology transfer. MIT is populated with a large number of star scientists, in science, engineering, and biomedical disciplines, who are committed to generating, disseminating, and preserving knowledge, and to working with others to bring this knowledge to bear on practical problems. In summary, the MIT story is about a formal, deliberate approach to commercialization, which is supported by a university mission advocated by university leaders who view MIT operating with industry. However, it is also a story of history, leadership by key individuals, and the development of a robust entrepreneurial culture.

The case evidence suggests that four attributes of a university are important in supporting spinoff activity. These are the science and engineering base of the university; the quality of research by university staff; the commitment to spinoff activity within management in the university (Leadership and Supporting Policies); and the culture within the university (Entrepreneurial Orientation of the university). The case also suggests that in addition to these four factors, there is a systemic process, whereby learning effects from previous success partially determine current spinoff activity. Finally, we suggested that the regional context influences the level of spinoff from a university. These factors could provide the basis of further research into efforts by universities to increase commercialization activity and spinoff activity. These factors deserve to be studied in more depth as a set of factors as the interaction of the factors are clearly important in understanding spinoff activity.

What can be learned from the MIT example? Our case suggests that there are some factors that can be replicated or emulated and some that cannot. History cannot be created; the influence of geography is fixed, at least in the short run; and while culture can change, it is often a slow process. On the other hand, the research portfolio of the university can be changed, albeit slowly. While this is not as easily done as might be possible in a hierarchically organized industrial firm, faculty can be persuaded and hiring slots can be directed towards fields with greater potential (O'Shea et al., 2004). The quality of research can be raised through hiring and promotion, provided that the resources are available. As other things are never equal, this may require more resources in some universities (Powers & McDougall, 2005). The third potential driver, administrative commitment, can be created. It must, however, be demonstrated in more than just words. Once again, resources must be allocated. A strong TLO can be a part of this. An attractive sharing with faculty of financial returns from commercialization can be another (Siegel, 2003b). A liberal policy on leave and time off is another. Finally, an insistence on traditional academic output (publications, etc.) in addition to commercialization may be required.

Attempts to increase spinoff activity within an institution are dependent on the efforts of the institution and on the support of external players such as government and industry. We believe so. Current practices and policies at MIT provide examples of how a university can achieve the twin objectives of excellence in academic research and contribution to economic and industrial

development. However, we caution that a simplistic attempt by an institution to replicate and transpose current policies and practices without a deeper and more holistic understanding of both their own history and MIT's history will probably be unsuccessful as they ignore the inter-related nature of the drivers of spinoff activity.

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Notes

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2. For a full and comprehensive review of the spinoff literature, please refer to O'Shea et al. (2004). For further literature regarding the changing role of universities in the commercialization process, refer to Chakrabarti and Lester (2002).
3. This figure excludes money received from Lincoln Lab, the government-sponsored Defense Research Labs.

Appendix A

Tables A1–A5

Table A1. Engineering school overall ranking

Rank	University	Score
1	**MIT**	**100**
2	Stanford	93
3	California – Berkeley	88
4	University of Illinois – Urbana – Champaign	83
5	Georgia Institute of Technology	77
6	California Institute of Technology	75
6	University of Southern California	75
8	Purdue University	74
8	University of Michigan	74
10	Cornell	73

Source: US News & World Report, 2005.

Table A2. Biological sciences ranking

Rank	University	Index score
1	Stanford	4.9
2	Harvard	4.8
2	**MIT**	**4.8**
2	University of California – Berkeley	4.8
5	California Institute of Technology	4.7
5	John Hopkins University	4.7
5	University of California San Francisco	4.7
8	Rockfeller University	4.6
9	Princeton University	4.5
9	Scrips Research Institute	4.5

Source: US News & World Report, 2005.

Table A3. Chemistry ranking

Rank	University	Index score
1	University of California – Berkeley	5.0
2	California Institute of Technology	4.9
2	Harvard	4.9
2	**MIT**	**4.9**
5	Stanford University	4.8
6	Scripps Research Institute	4.5
7	University of Illinois – Urban-Champaign	4.5
7	Columbia University	4.4
9	Cornell University	4.4
10	University of Wisconsin	4.4

Source: US News & World Report, 2005.

Table A4. Computer science ranking

Rank	University	Index score
1	Carnegie Mellon University	4.9
1	**MIT**	**4.9**
1	Stanford University	4.9
1	University of California – Berkeley	4.9
5	University of Illinois – Urban-Champaign	4.6
6	Cornell University	4.5
7	University of Texas – Austin	4.4
7	University of Washington	4.4
9	Princeton University	4.3
10	California Institute of Technology	4.1

Source: US News & World Report, 2005.

Table A5. Venture capital availability

Rank	State	Amount ($ in billions)
1	California	2,340.5
2	**Massachusetts**	**777.3**
3	Texas	294.3
4	New York	131.4
5	Maryland	235.6
6	Washington	143.8
7	Colorado	91.7
8	Georgia	158.3
9	Virginia	73.8
10	Florida	90.5

Source: Thomson Venture Economics, 2004.