PRELIMINARY

Entrepreneurs from Technology-Based Universities: An Empirical First Look

by

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Abstract

This paper provides an initial analysis of major patterns and trends in entrepreneurship among technology-based university alumni since the 1930s. We describe findings from two linked datasets joining Massachusetts Institute of Technology (MIT) alumni and founder information. The rate of forming new companies by MIT alumni has grown dramatically over seven decades, and the median age of first time entrepreneurs has gradually declined from about age 40 (1950s) to about age 30 (1990s). Women alumni lag their male counterparts in the rate at which they become entrepreneurs, and alumni who are not U.S. citizens enter entrepreneurship at different (often higher) rates relative to their American classmates. New venture foundings over time are correlated with measures of the changing external entrepreneurial and business environment, suggesting that future research in this domain may wish to more carefully examine such factors.

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1. Introduction

This paper provides an initial analysis of major patterns and trends in entrepreneurship among technology-based university alumni since the 1930s by asking two interlinked research questions: (1) Who enters entrepreneurship, and has this changed over time?, and (2) How does the rate of entrepreneurship vary with changes in the entrepreneurial business environment? In examining these questions in the context of alumni[1] and founder records from the Massachusetts Institute of Technology (MIT), our study also speaks to the important role of the university in facilitating entrepreneurship.

The national innovative systems literature has stressed the role of universities in generating commercially important technical knowledge via knowledge spillovers (e.g., Nelson, 1996). Various modes of academic knowledge diffusion to the private sector have been discussed in the literature. Such knowledge might enter the commercial realm, for example, when trained graduate students enter industry, professors consult to private entities, via conferences and interpersonal communication, or when academically-published research possessing commercial implications enters the public domain (e.g., Powell et al., 1996; Cohen et al., 2002; Agrawal and Henderson, 2002). In another strand of the literature, researchers have studied spin-off ventures started by university faculty and staff and commercialization of university-generated inventions via licensing to incumbent and start-up firms (e.g., Dahlstrand, 1997; Shane, 2002; DiGregorio and Shane, 2003; Vohora et al., 2004). University technology licensing, in particular, has been particularly intense in recent years (Mowery et al., 2001), with 214 academic institutions accounting for a total of 450 new start-ups through technology licensing in fiscal year 2002. Moreover, since 1980 4,320 new companies have formed based on university technology

[1] We use the term "alumni" throughout to include both male alumni and female alumnae.

licenses, with 2,741 still operating as of fiscal year 2002 [www.autm.net].[2]

Another way in which universities contribute to commercial activity via new venture creation is the attraction of individuals with complementary skills and goals to a common location, which is a by-product of fulfilling an educational mission. Increasingly, universities are seen as one of the keys to educating and attracting future entrepreneurs, as well as opening up new opportunities for firm creation. While the recent literature on the "entrepreneurial university" and academic entrepreneurship has focused on faculty entrepreneurs and university spin-off firms (e.g., Dahlstrand, 1997; DiGregorio and Shane, 2003; Etzkowitz, 1998; 2003; Nicolaou and Birley, 2003; Vohora et al., 2004), the university's entrepreneurial influence can be seen as extending to its students as well. Formal study of technology-based entrepreneurship dates back to the 1960s (Roberts, 2004). Yet the contribution of universities to entrepreneurship via students and alumni still needs much systematic analysis, particularly as related to changes over time.

Alumni from leading research universities are responsible for a host of important new ventures. For example, the Stanford website asserts that the university's "entrepreneurial spirit ... has helped spawn an estimated 1,200 companies in high technology and other fields."[3] Companies listed include Charles Schwab & Company, Cisco Systems, Dolby Laboratories, eBay, Excite, Gap, Google, Netflix, Nike, Silicon Graphics, Sun Microsystems and Yahoo!. For its part, the MIT website claims 150 new MIT-related firms founded per year, a total of 5,000 companies, employing 1.1 million and with aggregate annual sales over $230 billion.[4]

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[2] The distribution of start-ups coming out of universities is uneven, however, with some universities generating both more numerous and more important commercial technologies into the private world than others. For example, in fiscal year 2003 MIT and Stanford each had 17 licensed technologies become the bases of new ventures, which is many more than the average number of start-ups per U.S. university licensing office (about two).

[3] http://www.stanford.edu/home/stanford/facts/innovation.html (accessed September 1, 2005)

[4] http://entrepreneurship.mit.edu/mit_spinoffs.php (accessed September 1, 2005)

Companies founded by MIT alumni and faculty include Analog Devices, Arthur D. Little, Inc. (1886), Campbell Soup (1900), Bose, DEC, IDG, Intel, Raytheon, Rockwell, Texas Instruments, Teradyne and 3Com. Both universities claim E*Trade and Hewlett-Packard.

Clearly, research universities are important institutions for educating world-class technologists. But, among many other roles, they also provide an important social setting for students and faculty to exchange ideas, including ideas on commercial entrepreneurial opportunities. Disentangling the marginal impact of one life experience (albeit an important one, graduating from an institution of higher learning) from other experiences in contributing to the necessary skills and preferences for founding an entrepreneurial venture is a considerable challenge which we do not address. We have a more modest goal here.

The purpose of this study is to provide an initial and rare view of entrepreneurship patterns among graduates of MIT over several decades. This research serves to advance our knowledge of how founders have changed over time. To that end, instead of deriving empirical predictions from the extant literature (which is limited in this domain), we devote our attention to describing what we found in the data on the evolution of entrepreneurship over time.

The fact that the founders in our study are all graduates of the MIT imposes some degree of uniformity on the sample of entrepreneurial ventures, which is attractive since entrepreneurs and new ventures are quite heterogeneous. While such a sample is not necessarily representative of the entire spectrum of self-employment (e.g., Blau, 1987; Carroll and Mosakowski, 1987; Parhankangas and Arenius, 2003), our focus is to better understand the changing nature of entrepreneurship among graduates of a prominent research university over a relatively long time span. The brief list cited above of some of the more well-known companies founded from research universities suggests that studying these relatively homogeneous entrepreneurs

emanating from MIT and comparable institutions is an important undertaking, as such firms are responsible for considerable value creation. The firms formed by the entrepreneurs in our dataset actually include a great deal of variation across both industry sectors (spanning service and manufacturing industries, with varying degrees of technological reliance) and venture sizes (a companion paper is devoted to analyzing entrepreneurial firms founded by the entrepreneurs discussed here).

We present our discussion and results in two stages. We first analyze determinants of who engages in entrepreneurship, and then examine how the rate of entrepreneurship varies according to the business environment in a second stage. We interpret our results as suggesting that the volume of entrepreneurial activity responds to the business and entrepreneurial environment, and that differences in individual characteristics shape the transition to entrepreneurship, both within and across time periods.

The remainder of the paper is organized as follows: section two reviews the prior literature on individuals and entrepreneurship, section three discusses the data and presents results on characteristics and rates of those entering entrepreneurship over time. Section four examines the changing entrepreneurial business environment. Section five discusses the study's findings and limitations, together with areas for future research. A final section concludes.

2. Transition to Entrepreneurship

Entrepreneurial action has been identified as both vital to economic growth and an important efficiency-inducing mechanism in the economy (Schumpeter, 1943). Shane (1995) shows that the national growth in the prevalence of entrepreneurial firms between 1947 and 1990 enhanced real economic growth in the U.S. economy as a whole. For these reasons, the

innovation and entrepreneurship literatures have long been interested in the question: What causes some people to start companies when most do not? The literature analyzing this question has examined four categories of explanations: (1) basic demographic factors such as age, ethnicity and gender, (2) training and experience effects, (3) cognitive differences between individuals, and (4) financial and opportunity cost-based rationales. Our purpose here is to briefly review these explanations (in the order listed) to provide context for interpreting results from the MIT dataset. Clearly, this literature covers a large terrain; however, the literature does not provide analysis over a long time span, which may be necessary to better understand factors that drive changes in the rate of entrepreneurship.

The first class of explanations for entering into entrepreneurship emphasizes demographic factors, and spans areas such as religious background (McClelland, 1961) and the presence of self-employed parents (Dunn and Holtz-Eakin, 2000; Roberts, 1991; Sorensen, 2005). A number of studies have suggested that age may play a role in the decision to start a new venture as well, with an "aging out" phenomenon affecting those in their upper 40s and later years if they had not earlier started a company (Levesque and Minniti, forthcoming). Empirical evidence appears to support this assertion (Roberts, 1991).

Ethnic and immigration status may also play a role in entrepreneurship. Entrepreneurship rates appear to be high among members of some immigrant communities, including Swedish technological entrepreneurs and recent Silicon Valley high-tech start-ups (Utterback et al., 1988; Saxenian, 1999; 2002). More generally, the decision to enter self-employment among members of immigrant communities depends on the size of the ethnic market, as well as on human capital characteristics such as language skills (Evans, 1989).

The literature on gender and entrepreneurship, while limited, highlights two areas. One group of studies suggests that women entrepreneurs tend to concentrate in certain industries, typically personal services and small-scale retail (e.g., Bates, 2002). A second group of studies examines differential motivations for entering entrepreneurship according to gender. Men tend to be more motivated by wealth creation, whereas women have family-oriented motivation and desire the flexibility that entrepreneurship offers, though these differences are less apparent among women and men who do not have children (DeMartino and Barbato, 2003).

These differences across gender also appear to be conditioned on several environmental influences. Career advancement obstacles may induce women to go into business for themselves at a disproportionately high rate (Buttner and Moore, 1997), the presence of children and the provision of child care by the husband increases self-employment among women (Caputo and Dolinsky, 1998), and the effect of parental self-employment on one's likelihood to enter entrepreneurship runs primarily along gender lines (Dunn and Holtz-Eakin, 2000).

A second class of explanations for transitioning into entrepreneurship has emphasized training, career histories, and other experience. Exposure to entrepreneurial experience through household or personal experience increases the likelihood of entrepreneurship (Carroll and Mosakowski, 1987; Roberts, 1991; Sorensen, 2005). The recent spin-off literature has emphasized both the characteristics of the parent firms (e.g., Gompers et al., 2005) as well as characteristics of the individuals (e.g., Shane and Khurana, 2003) as important determinants of the likelihood to spin off new ventures.

Recent studies have connected educational training with entrepreneurship, which appears to be a plausible explanation, as countries with a higher proportion of engineering college majors

experience faster economic growth (Murphy et al., 1991).[5] Baumol (2004) suggests that the type of education appropriate for technical knowledge mastery may be significantly different than the type of creative thinking needed for entrepreneurial opportunity recognition and exploitation. In a related effort, Lazear (2004) developed a theoretical model and tested it on a data set of Stanford business school alumni, showing that an important determinant of entrepreneurship is the breadth of an individual's curriculum background, suggesting that entrepreneurs tend to be generalists rather than specialists. The Lazear (2004) study does raise the question of whether it is the higher number of different roles that induces entrepreneurship by providing a necessary balance of skills/knowledge or by reducing the payoff to a traditional career based on building a specific skill set. As well, these payoffs may be importantly affected by regional labor market conditions. For example, Roberts (1991) found that MIT-based technical entrepreneurs (who tended to exhibit more stable employment patterns in the East Coast) were quite different from Stanford-based technical entrepreneurs (who tended to "job-hop" in the West Coast labor market).

A third set of explanations for individual differences in transitioning into entrepreneurship emphasizes cognitive factors (e.g., Mitchell et al., 2000). For example, Douglas and Shepherd (2000) propose a model in which individual attitudes toward risk-aversion, independence and work determine entrepreneurial entry based on utility comparisons. Empirical evidence has been offered in this domain to support the extent of counterfactual thinking and regret (Baron, 2000) and controlling perceived risk versus perceived outcomes (Sarasvathy et al., 1998). In addition, Roberts (1991) found that those with "moderate" needs for achievement and

[5] The direction of causality may be reversed here, however: countries with faster growth may provide more engineering jobs and may support more engineering education.

power, as well as heavy orientation toward independence, were more likely to become entrepreneurs.

The final set of explanations for individual differences in transitioning to entrepreneurship deals with opportunity costs and financial access. Both theory and empirical evidence have supported the claim that the lower the opportunity costs of individuals, the more likely they are to start a new firm (Amit et al., 1995; Iyigun and Owen, 1998). Gimeno et al. (1997) demonstrated that those with higher switching costs into other occupations are more likely to remain in entrepreneurship, even with low performing firms. Additionally, employees are more likely to leave their existing organization to start a new firm when there has been a slowdown in sales growth in the existing firm (Gompers et al., 2005).

The financial capital of parents and to an extent, the income of the potential entrepreneur has also been linked with entrepreneurship (Dunn and Holtz-Eakin, 2000). The effects of financial constraints on the formation of new firms are also seen in the negative correlation of tax rates and self-employment in lower tax brackets (Blau, 1987) as well as in the increased propensity to be self-employed following an inheritance or gift (Blanchflower and Oswald, 1998). More generally, in a model of the supply of employees becoming entrepreneurs, Hellmann (2003) shows that the munificence of funding for new ventures determines the rate of transition from employee to entrepreneur.

3. The MIT Data and Transitions to Entrepreneurship

To shed light on the transition to entrepreneurship at the individual level, we present a new dataset composed of 42,930 records of MIT alumni (the "alumni" data) responding to a 2003 survey of all living alumni. Of these alumni 7,798 individuals indicated that they had

founded at least one company. These individuals were then mailed another survey asking detailed questions about formation of their firms. 2,111 founder surveys (the "founder" data) were completed, representing a response rate of 27.1%. While the alumni data contain only basic demographic information on date of birth, country of citizenship, gender, major at MIT, highest attained degree and new venture founding history, the founder data contain more detailed information about firm formation. Our confidentiality agreement with MIT permits only these brief descriptions of the data and data collection. The present paper primarily analyzes information about individuals, while a companion paper is devoted to the ventures formed. One of the key features of this interlinked dataset is its long time horizon in the cross section (1930-2001) that allows us to analyze trends over several decades.

3.1 What can be examined and what cannot?

The advantages of the MIT alumni founder dataset in informing the literature on entrepreneurial transitions are the number of decades covered, the very large number of observations, as well as the ability to compare the founders' characteristics along a number of dimensions with their classmates who had largely the same educational experience while at MIT but did not become entrepreneurs. We also see a wide range of firm sizes, number of operating years, and outcomes so we do not necessarily share the limitation of other entrepreneur datasets in only sampling the most successful founders. One key difficulty in interpreting these data is that there is temporal right-censoring in that we cannot know who of the more recent graduates will become entrepreneurs, especially given the frequent long lag from graduation to first firm founding. Also, while there is a large amount of information on the founders, the number of matching variables on all alumni is more limited.

In regard to the personal characteristics of the entrepreneurial dataset that we now

describe, we can analyze and report on a number of characteristics. These include the overall temporal pattern of change in the number and intensity of founder experiences among these alumni. We can determine their ages when their first entrepreneurial acts occurred, and how long they delayed after graduation from MIT and/or other universities as well. The data permit separation by gender, country of origin, and academic field of study while at MIT.

However, we lack much data that the literature has presented as important. For example, we do not have parental or family background information, including parental careers, religion or wealth. We do not have good measures of the skills or variety of roles played by the alumni prior to their becoming entrepreneurs. We also lack information on cognitive characteristics of the entrepreneurs, opportunity costs they might have perceived in becoming entrepreneurs, and information on their motivations in starting their firms. These deficiencies constrain our areas of current analyses while providing good opportunities for future research direction.

3.2 Founder characteristics

3.2.1 Incidence and demography of entrepreneurship

Figure 1 shows dramatic growth over the past seven decades in the number of MIT alumni founding their first companies, including additional curves for the firms founded by women and those founded by alumni who were not U.S. citizens. Clearly males and U.S citizens account for the vast bulk of the MIT alumni entrepreneurs over this entire period. A total of 747 such alumni reported started their first firms during the decade of the 1990s. Women founders begin to be visible in the 1950s and grow to about 10.1% of the sample by the '90s. Non-U.S. citizens as entrepreneurs begin slight visibility in the 1940s and grow steadily to about 17.2% of the new firm formations during the decade of the 1990s. These data are normalized in Figure 2, which portrays the number of foundings during that decade divided by the number of alumni in

existence up until that decade (which we refer to as "entrepreneurial intensity") for all alumni, as well as for the women and non-U.S. citizen subsets.[6] The normalized data also show significant growth overall but with some additional insight. Overall alumni entrepreneurial intensity develops rapidly through the decade of the 1980s, up to a rate of formation of 17 new first firms per 1000 living alumni, slightly turning down in the 1990s. The intensity of new entrepreneurial startup formation by women grows rapidly from 1950 on, up to about 10 per 1000 women alumnae, still considerably below the male rate of firm formation. Relative to their numbers, non-U.S. citizens become entrepreneurs even more rapidly than their U.S. alumni counterparts, with the exception of the immediate post-World War II decade, to a rate of about 18 new companies being formed per 1000 alumni in the decade of the 1980s, with a slight turndown in the 1990s. In section 3.2.4 we provide data that indicate that most of the non-U.S. alumni entrepreneurs have been coming from Asia, Europe and Latin America, with each continent in recent decades accounting for approximately 10% of the entire sample of MIT alumni first-time startups.

These results mirror those found by Gartner and Shane (1995), who find an acceleration of new venture foundings between 1957-1992, particularly after 1980, and by Blau (1987), who shows that in the early 1970s the general trend toward decreasing self-employment in the nonagricultural sector reversed and has continued to rise since then.

3.2.2 Age of first time entrepreneurs and lag from graduation

Along with the sheer increase in numbers has been the dramatic reduction beginning in the 1960s in the age at which "the entrepreneurial act" occurs, as shown in Table 1 (panel A).

[6] The MIT undergraduate class grew from about 900 per year in the 1950s to about 1100 in subsequent decades. Graduate school enrollments have grown considerably as well over the same time period, including in particular the institutionalization of the MIT Sloan School of Management in 1952. Taking these changes into account via normalization per 1000 alumni at each decade helps to clarify the underlying trends.

The shift over the past six decades from starting a company in a founder's 40s to doing so at the age of 30 (at the median) has multi-dimensional implications for entrepreneurship as previously being a mid-life career change to becoming an initial choice of a lifetime career. The differences in organizational work experience, network accumulation, wealth accumulation and family responsibility situation, among other changes, all strongly accompany this shift in the age of founding. The distribution of entrepreneurial ages at their times of first foundings also has changed over the past 40 years. Figure 3 shows two frequency distributions of MIT alumni entrepreneur ages for firms founded in the 1980s and for those founded in the 1990s. Also added to the figure is the age distribution of entrepreneurs who came from several MIT laboratories and departments prior to 1970 (many were MIT alumni), documented earlier by Roberts (1991, Figure 3-3 used with permission). Note the general shifts in the three curves over the years. The distributions show that the more recent entrepreneurs include more from the younger age brackets as well as more from the late 40s and 50s age brackets. Prior to the 1970s 23% of the first-time entrepreneurs were under 30 years of age; during the 1970s that number grew to 31%; in the 1990s 36% of the founders were under 30. Prior to the '70s 26% of the first-time founders were over 40 years of age; during the 1970s 28% were older than 40; and in the 1990s 35% were older than 40.

Related to the decline in age distribution is the delay from graduation to founding a first firm, as shown in Figure 4. In this figure, the time lag for graduates from the more recent decades drops to as low as 4 years from graduation during the "bubble" years of the 1990s. Interpreting the figure is challenging since lags in more recent time periods do not account for those individuals who will become entrepreneurs in the future, i.e. right-side censoring of the

data (Figure 5 plots the median lags[7] as an imperfect solution—and finds a consistent time pattern). Note that the drop in time lag for men is approximately the same as for women over the full duration that women entrepreneurs have meaningful numbers in the dataset.

3.2.3 Educational characteristics

Examination of the founder characteristics by educational degree attainment in Table 1 (panel B) shows gradual changes across the decades of new company formations from over 50% down to below 40% bachelor's degree recipients, a rise in percentage of master's degree holders to 40% and more, with doctoral recipients gradually moving upward toward 20%. These numbers changed in the post-World War II period with the rapid growth of graduate education at MIT in engineering and the sciences, especially at the doctoral level, and the later growth of those enrolled for the master's degree at the MIT Sloan School of Management.

In Figure 6 we show the educational characteristics differently, by plotting the proportion of those entering entrepreneurship normalized by the number finishing with each specified degree in each decade. This figure is again right-side censored in that we do not know who of recent decade graduates will start first firms after 2001, the last date for which we have founding data. We also do not account for any differences in lag for SB, SM and PhD recipients in their paths toward entrepreneurship. But what interests us is the significant increase over time in the proportion of PhDs becoming entrepreneurs, becoming almost the same by the present time as those receiving Master's degrees. Bachelor's degree recipients, in contrast, decline in becoming entrepreneurs, at least in their early years post-degree. This is presumably explained in part due to the increased fraction of Bachelors graduates going on for advanced degrees. Fewer and fewer MIT SB degree holders enter the job market, including that for starting new firms, with just their

[7] Bachelor's graduates were excluded from this calculation to eliminate the effect of the major trend of an increasing percentage of them going directly to graduate school rather than into a job.

Bachelors degree.[8]

A final educational aspect is the general area of MIT study of these alumni entrepreneurs. In Figure 7 we show by decade of firm founding the percentage breakdown by general field of study of the MIT alumni founders. MIT is organized by academic departments within five schools. The departments have had some small number of changes over the years, but the five schools have remained relatively stable as Architecture and Urban Studies, Engineering, Humanities and Social Science, Management, and Science, with the MIT Sloan School of Management becoming MIT's fifth school in 1951 (it had been a department since 1914). The data show that while engineering graduates represent the bulk of those entering entrepreneurship over the time period of the sample, science and management graduates have increased their representation in recent decades.

In Figure 8 we show the normalized percentages of entrepreneurs by school, again using the numbers graduating in each decade as our bases for normalization. We face the same right-side censoring as observed previously, but we presume that the overall trends in areas of study are not affected by this censoring. Despite increased participation over time from science graduates, the percentage of them who become entrepreneurs is still the smallest of all background areas of study, over essentially the entire period of time studied. Proportionately from 50 to 100 percent more MIT engineering graduates as science alumni eventually become entrepreneurs. Management graduates overall seem to be as inclined proportionately to become entrepreneurs as MIT engineering graduates. Architecture alumni are proportionately the most likely among graduates of all the MIT schools to strike out on their own, no doubt reflecting a

[8] For the period 1994-1996, approximately half of MIT graduates with an SB entered industry and half entered graduate school directly (http://web.archive.org/web/*/web.mit.edu). The number entering graduate school directly hit a low of 38% in 2001 to 2002 and has since increased to 67% for the 2003 to 2005 period (http://web.mit.edu/facts/graduation.shtml). (Web sites accessed September 1, 2005).

dominant "industry" structure of large numbers of small architectural practices, with relatively frequent changes in partnerships.

Table 1 (panel C) highlights some specifics of the educational backgrounds of the MIT alumni, showing for comparison the percent of all alumni founders by decade for only three MIT departments: electrical engineering and computer sciences (EECS), biology/life sciences, and management. EECS has by tradition been the largest department at MIT and the most evident home of its entrepreneurial offshoots. Biology/life sciences is an up-and-coming "technology change area" and we wish to portray its entrepreneurial inclinations. Management appears to have established itself as a common ground for entrepreneurial interest development and we want to examine how deeply rooted are these indicators. The data show that the percentage of founders graduating with degrees in biology/life sciences has indeed increased over the years, but appears to have leveled off in recent decades at around 5%. The percentage of EECS majors represented among founders remains the highest at around 20% and those with management degrees hover around 15%. Both EECS and management appear to be relatively stable in their supply of entrepreneurs over the decades.

3.2.4 Geographic origins

Figures 1 and 2 show the dramatic increase in number and entrepreneurial intensity of those MIT alumni who had non-U.S. citizenships. These data are impressive but may still understate the number whose country of origin is not the United States. Some percentage of the alumni who had been born elsewhere remained in the U.S. and had become U.S. citizens by the time they formed their first firm. Figure 9 shows the time trends in the proportion of founders by non-U.S. global geographic region at the time they formed their first companies. While U.S. citizens still account for about 85% of the new startup alumni entrepreneurs, proportional to their

graduating numbers at MIT, the alumni from almost every other region of the world have a higher likelihood of firm formation.

3.3 Testing the founder characteristics' influence on firm formation

From the information provided in section 3.2 it is clear that the MIT founder data across 70 years strongly show overall and impressive increases in the entrepreneurship phenomenon by absolute number, by youthfulness, by gender and by national origin. In order to better understand the comparative importance of these factors in firm formation, as well as to account for the right-censoring of the data, we turn to a multivariate regression analysis. We employ Cox (1972) hazard regression models for two reasons. First, the model is semi-parametric, so that we can estimate the impact of independent variables on the hazard of founding a firm while being agnostic about the baseline hazard function. Second, the model explicitly takes the timing of events into account (by estimating the probability of founding a firm in a given year conditional on not having founded a firm up until that time period), and adjusts for the right-censoring of the data. In the regressions, subjects start being "at risk" of founding a firm at the time of their birth, and a "failure" event occurs the year the individual founds a firm (otherwise, the founding year is considered censored for that individual as of the year 2003). Reported coefficients represent hazard ratios, with values above 1.0 representing increases in the hazard of founding a firm and vice-versa for values below 1.0. Statistically significant estimates are indicated through asterisks. Since founding a firm is a relatively rare event in the overall data, and because we need the timing of events to conduct the hazard analysis, we construct a stratified random sample drawn from the larger alumni dataset. To construct the sample used in the multivariate regressions, we first selected all 1,626 individuals known ex post to have founded a firm. We then matched these individuals in a five to one ratio with randomly-selected alumni who had not founded a firm as

of 2003, conditioning only on birth year. The statistics literature (e.g., Breslow et al., 1983) suggests little loss of efficiency so long as approximately 20% of a sample has experienced the event of interest.

Table 2 presents variable definitions and summary statistics. Table 3 shows the results of four models: 3-1, graduation year and gender; 3-2, area of study at MIT; 3-3, geographic region of citizenship; and 3-4, a combined model with all the above factors included. Model 3-1 shows that later cohorts of graduating alumni experienced increased hazards (i.e., likelihoods) of founding a firm by 2.2% per graduating year. As well, across the time span covered in the data, male alumni were almost twice as likely to found a firm relative to their female counterparts. Model 3-2 shows that, relative to natural science graduates, engineering, management and architecture (but not social science) graduates were more likely to start firms. Model 3-3 indicates that relative to U.S. citizen alumni, alumni hailing from Latin America and the Middle East were significantly more likely to be firm founders, while those coming from Asia had a lower hazard rate. Finally, model 3-4 simultaneously examines all the prior effects. While the graduation year, gender, and disciplinary background effects remain stable in their economic and statistical significance, the country of citizenship effects are modified somewhat. Latin American citizens had a 56% higher hazard of founding a firm relative to U.S. citizens (the Middle East result is no longer statistically significant), while Asian citizens were 37% less likely to start a firm relative to U.S. citizens. These basic results are robust to stratifying the baseline hazard according to disciplinary background (allowing engineering, management, architecture, social science, and natural science majors to have their own unspecified baseline hazard functions).

Since we are interested in temporal changes in entrepreneurship, the analysis in Table 4 divides the sample into quartiles of birth year cohorts and estimates fully-specified models

(mirroring the final specification of Table 3) for these four time sub-samples. Being male and studying either engineering, management or architecture retains significance in (almost) all these birth periods. Note that the hazard for male relative to female alumni has increased dramatically for the later birth cohorts. Non-U.S. alumni over time in general show the same general patterns as shown in Table 3. The graduation year effects disaggregated in this way suggest that later graduation years *within* cohorts has a negative or zero effect on the founding hazard, whereas the average graduation year effect across the entire time span is positive.

4. Changes in the Entrepreneurial Founding Environment

The figures and tables from the prior section highlight interesting long term patterns of individual-level entrepreneurial entry among MIT graduates. While the rate of transition into entrepreneurship has increased overall, these rates differ by gender, academic major, and country of origin. Explanations for these empirical patterns might be grouped into three broad categories: (1) shifts in entrepreneurial opportunity through, for example, scientific and technical advances or changes in government policies, (2) shifts in values, preferences and attitudes toward entrepreneurship, and (3) changes in the entrepreneurial infrastructure, such as the availability of professional services and the strength of intellectual property protection. In this section, we discuss each of these areas, and conclude with an analysis of the relative empirical importance of the factors.

4.1 Changing Entrepreneurial Opportunities

Emerging technologies and the new industries that they sometimes generate are associated with bursts of entrepreneurial activity (Utterback, 1994). Thus, one reason for increases in entrepreneurship may be new technological opportunities. For example, the

development of the biotech industry occurred physically and temporally alongside those developing the underlying science (e.g., Zucker et al., 1998).

If technological opportunities are behind the general increase in entrepreneurship, then we should see the increase concentrated in certain industries. Consistent with this proposition, we find in our companion paper on ventures started by MIT alumni-entrepreneurs larger relative increases in new software and pharmaceutical, biotechnology and other medically-related firms formed by MIT alumni.

Some have argued that the discovery of opportunities for entrepreneurship is a function of the information distribution across society (Hayek, 1945; Shane, 2000). Since one must discover an opportunity before one can act on it and start a new firm, changes in the distribution of information may result in shifts in the level and type of entrepreneurship. While individuals will have different experience and be exposed to different information (moreover, information processing takes place differently), the MIT alumni sample imposes some desirable homogeneity on this dimension (e.g., levels of human and social capital) relative to more heterogeneous samples.

Finally, the era of U.S. government deregulation, primarily between 1976 and 1990 in a number of significant industries (e.g., Jensen, 1993), represents another important entrepreneurial opportunity window. A study of the U.S. electric power industry, for example, shows that deregulation can cause a rapid increase in entrepreneurial activity (Sine and David, 2003).

4.2 Changing Attitudes toward Entrepreneurship

A second possible explanation for the observed empirical patterns is shifting attitudes toward entrepreneurial careers. Such shifts may be tied to changing expected financial rewards

and/or social attitudes.

In the realm of financial returns sparking entrepreneurial interest, the large number of new venture liquidity events, particularly in Silicon Valley and Massachusetts, during the late 1990s altered the benefits (actual or perceived) and incentives to enter entrepreneurship. Entrepreneurship decisions are also based on financial opportunity costs, which may be lowered during periods of high unemployment or economic recession, and may be affected by changes in public policy such as tax law.

The second aspect of changing perceptions of entrepreneurial careers is tied to social attitudes. Recent increases in university-industry interactions may have an impact not only on faculty entrepreneurship (Murray, 2004; Oliver, 2004; Powell et al., 1996), but on students' perceptions of norms and opportunities as well (Etzkowitz, 1998). This can lead to strong demonstration effects. New sets of norms appear to be spreading throughout the academic community leading to more favorable attitudes toward commercially-oriented research (Owen-Smith and Powell, 2001), even in countries with little prior history of academic entrepreneurship (DeGroof and Roberts, 2004). One important way in which information and norms about academic technology commercialization is spread is through networks of academic co-authorship (Stuart and Ding, 2005).

Beyond academic community norms, the phenomenon of innovation arising from joining inventors and entrepreneurs with dispersed yet complementary skills and knowledge (such as in open source software development) may also contribute to changing environment for entrepreneurship (von Hippel, 2005). In addition, supporting institutions, related firms, complementary services and prior precedent are likely to make subsequent new venture creation

more likely and more successful, both in the academic and non-academic contexts (e.g., Owen-Smith and Powell, 2004; Stuart and Sorenson, 2003).

Finally, while this discussion of factors that shape attitudes toward entrepreneurship has been segmented into financial and social, each likely influences the other. For example, differences in the social stigma associated with entrepreneurial failure may impact levels of entrepreneurship across regions or over time, which can have real implications for the cost of financial capital (Landier, 2002).

4.3 Changes in Entrepreneurial Infrastructure

While there are likely to be numerous important changes in the infrastructure for entrepreneurial activity over the past several decades, we highlight two here: (1) the rise of institutionalized venture capital and (2) the strengthening of intellectual property protection. The financial capital requirements associated with new venture founding and development can constrain the transition to entrepreneurship, and so academic work in entrepreneurial finance has focused on the economics of the venture capital industry (e.g., Gompers and Lerner, 1999). The rise and institutionalization of venture capital can be traced to the formation of American Research and Development Corporation in 1946 (Hsu and Kenney, 2005), though the munificence of venture capital funding has ebbed and flowed since that time. Between 1946 and 1977 the creation of new venture funds amounted to less than a few hundred million dollars annually (Kortum and Lerner, 2000). Starting in the late 1970s and especially in the late 1990s, fundraising in the venture capital industry sharply increased (Kortum and Lerner, 2000; VentureOne, 2000).[9] In the years since 2000, following the bursting of the technology bubble and September 11, 2001, the levels of investment have dropped (from a peak of about $100B),

[9] In 1979 an amendment to the "prudent man" rule by the Department of Labor allowed pension managers to invest in high-risk assets, including venture capital.

though still amount to about $18B in annual disbursements.[10]

A second component of the entrepreneurial infrastructure is the strength of formal intellectual property rights (IPR) through patent protection. As has been documented elsewhere (e.g., Gallini, 2002, and references therein), a series of policy changes starting in the 1980s extended and strengthened the relative protection that patents provide.[11] Stronger IPR protection increases the returns to innovation via a decrease in the risk of expropriation (Gans and Stern, 2003), which may act to encourage entrepreneurial entry.

4.4 Statistical Evidence

In an effort to adjudicate among some of the plausible explanations discussed, we present a statistical analysis. The unit of analysis is a year, and the dependent variable is the annual *number of first firm foundings* by MIT alumni between 1930 and 2003. Using negative binomial regressions due to the count nature of the dependent variable, we examine how well various regressors that reflect annual changes in the business and economic environment explain the variation in yearly firm foundings. The summary statistics and variable definitions for this analysis are found in the second half of Table 2, and the regression results are presented in Table 5. Each specification controls for the number of graduating students, and successively introduces measures of the entrepreneurial environment. Each of the independent variables is lagged by one year to account for adjustment times, though the results are largely insensitive to both contemporaneous specifications as well as lags of two and three years. Column 5-1 introduces a parsimonious regression, with *number of graduates* and *patents issued* as the sole right side

[10] National Venture Capital Association, http://www.nvca.org/ffax.html (accessed September 1, 2005).

[11] In 1980, the *Diamond v. Chakrabarty* decision allowed the patenting of life forms and similar decisions by the U.S. Supreme Court extended patenting to software (1981, *Diamond v. Diehr*), financial services and business methods (*State Street Bank and Trust v. Signature Financial Group*) (Gallini, 2002). In 1982 the creation of the Court of Appeals of the Federal Circuit resulted in an increase in the percentage of patents upheld on appeal from 62 percent during 1953-1978 to 90 percent during 1982-1990 (Gallini, 2002). In addition the Trade-Related Aspects of Intellectual Property (TRIPs) agreement extended the life of some patents from 17 to 20 years in 1994. Finally, in 1984 the Hatch-Waxman Act also extended the length of patent protection for drugs.

variables. While *patents issued* can proxy for several concepts such as technological inputs, outputs, or opportunity, the variable is positive and statistically significant, with an implied incidence rate ratio (IRR) of 1.023 (an additional 1000 patents awarded is associated with a 1.023x increase in the number of new ventures started). A second specification, column 5-2, examines the role of *venture capital disbursements* in the prior year. The estimated IRR of this variable, 1.062, is positive and statistically significant. A third column examines the macroeconomic environment using measures for a *recessionary economy*, *gross domestic product* (GDP), *inflation rate*, and the *market capitalization of the New York Stock Exchange* (NYSE). While the *GDP* and *NYSE* measures are estimated with statistically significant coefficients, their estimated economic importance is small. On the other hand, the dummy for *recessionary economy* is estimated with a positive and economically large coefficient (IRR=1.21) but is not statistically significant at the 10% level (though it is in the fully specified model, column 5-4). Putting all of these entrepreneurial environment effects together in the final column does not qualitatively change the results discussed above. Furthermore, in all of the specifications in Table 5, the variable *number of graduates* is positive and statistically significant (which correlates with the passage of time, as the MIT graduating class has been increasing over time). There is empirical support for changing technological opportunity (patents), venture capital activity, and financial opportunity costs (recessionary economic environment) in explaining variation in new venture initiation.

Care should be used in interpreting these results, not only because of the limited sample size, but also because right-censoring may be an issue in these analyses. As well, there are a number of other shifts in the entrepreneurial environment which we are not able to statistically identify,

for example the cluster of events at the end of the 1970s and beginning of the 1980s (such as the changes in the IPR and venture capital funding environment, as previously discussed).

5. Discussion

In this section, we summarize the main results and discuss possible future research directions based on our findings from the MIT alumni dataset.

5.1 The Decline in Age and Lag Time of First-Time Entrepreneurs

Table 1 (panel A) shows the declining median age of entrepreneurs beginning their first company from about 40 years in the decade of the 1950s to about 30 years in the decade of the 1990s. The decreasing lag from graduation to first entrepreneurial act is documented in Figures 4 and 5. A host of factors, including the changing entrepreneurial environment discussed in Section 4 likely contributes to these trends.

We see two areas for future research in this domain. First, what are the consequences of more youthful entrepreneurs from a business and public policy perspective? For example, how does the effect of less work experience at established companies trade off against new venture development via learning by doing? Second, the age distributions shown in Figure 3 indicate not only that more individuals are becoming entrepreneurs at younger ages, it appears that more persons are becoming entrepreneurs at older ages too, with a longer stretched out tail in the founder age curve. Among the following plausible explanations (or others), which is the most salient? (1) the growing tendency to work past a 65-year retirement target that has become obsolete in the U.S. as a result of anti-age discrimination laws; (2) increasing life span and individuals' desire to stay gainfully employed and active; (3) declining corporate loyalties that formerly had employees working for the same company until retirement; and/or (4) shifting types of entrepreneurship at older ages, e.g., through independent partnerships.

5.2 The Gender Imbalance among Entrepreneurs

The growth of women entrepreneurs appears to mirror the number of women graduating from all levels at MIT (rising from just over 10 female graduates (1%) in the 1930s to 43% of undergraduates and 30% of the graduate population in 2004-5).[12] At the same time, women have lower hazard rates of entering entrepreneurship relative to their male counterparts (and the gap appears to be growing larger over time).

Based on these findings, we highlight two potential areas for future research in this domain. First, a more systematic evaluation of the changing opportunity costs to entering entrepreneurship for women versus men would be useful. For example, the observed empirical pattern would not be surprising if the opportunity cost of an entrepreneurial career for women grew much faster than that for men over the time period. Second, while there has been increasing research on financial obstacles that differentially affect men and women (e.g., Hart et al., 2001), research on other potential impediments to female-founded venture initiation and growth would be welcome.

5.2 The Increase in Non-U.S. Entrepreneurs.

Figures 1 and 2, amplified by Figure 9, indicate the significant growth in both numbers of non-U.S. citizen MIT entrepreneurial alumni and the rate at which they exceed their U.S. classmates in becoming entrepreneurs. While there is variation among the non-U.S. citizen groups (European MIT alumni appear more entrepreneurial relative to U.S. alumni; Asian alumni less so), this area seems neglected in the research literature (Saxenian 1999; 2002 are notable exceptions).

A number of plausible explanations are possible for these empirical patterns. For example, foreign individuals who travel to the U.S. for their education (especially to an elite

[12] http://web.mit.edu/facts/enrollment.shtml (accessed September 1, 2005).

university) are likely to be among the most entrepreneurial and financially well-off individuals in their home countries. If U.S. labor market options are not as open to immigrants relative to the American counterparts, immigrants may face lower opportunity costs to becoming entrepreneurs. Finally, some foreign graduate students would like to remain in the U.S. after graduation yet cannot due to expiring student visas. Under U.S. immigration law individuals wishing to start a new business may receive a non-immigrant visa as a "treaty investor" with no maximum period of stay.[13]

Students may also elect to return home to practice in their home environs the models of entrepreneurship they have observed in the U.S. For example, two of the three leading internet firms in China, Sohu.com and Sina.com, were founded and led, respectively, by an MIT alumnus, Dr. Charles Zhang, and a Stanford alum, Ben Tsiang. In any case, future research that provides empirical evidence related to the phenomenon of differing rates of entrepreneurship among foreign citizens and in foreign citizens as compared to U.S. citizens would be welcome.

5.3 Limitations

In interpreting the results from this study, it is useful to keep in mind three data-related issues: representativeness, response rates, and self-reporting. The first issue relates to how representative this sample is of entrepreneurship in general. The data for this study come from alumni of an important academic institution historically at the intersection of technology and commercialization. It is important to note that these are alumni and therefore the sample is not limited to those currently associated with MIT or to technology coming from MIT. While these individuals have all passed through MIT for a period of education, they have had diverse experiences before matriculation, while at MIT, and since graduation. Therefore, while there is

[13] This status is renewable indefinitely (http://www.expertlaw.com/library/immigration/e2_visas.html) (accessed September 1, 2005).

no doubt that individuals in the sample are relatively homogeneous in some respects, they are quite different in others (as reflected in both the type of ventures they start as well as in their outcomes). We do not claim generalizability across the spectrum of entrepreneurial activity; however, we believe that the sample represents an interesting and important population of individuals over a significant time span.

A second issue is possible response bias. It may be that graduates who started a company but were unsuccessful did not report on these failed firms, either by omitting them from their responses or not participating in the study at all. As an associated issue, it is likely that the responses from non-U.S. alumni are somewhat less representative than their U.S.-based counterparts due both to potentially less complete contact records as well as fewer reminders to complete the survey. In addition, first and second generation U.S. citizens whose parents immigrated to this country are placed together with U.S. citizens whose families have a long history in the country, even though there may be behavioral differences across these two groups with respect to entrepreneurial activity.

Finally, there is the issue of self-reporting. Older respondents, especially those who have started multiple companies, may display a memory bias in which some companies, possibly those which were relatively unsuccessful, are not reported. This may lead to the appearance that younger entrepreneurs are starting more (though less successful) firms on average. Similarly, if cultural attitudes toward entrepreneurship have indeed changed over the years, younger entrepreneurs may have been more likely to respond to the survey and to indicate that they had founded a firm. Older entrepreneurs may also have been less likely to respond to a university survey due to the sheer number of years since their affiliation with MIT.

While these limitations may provide reason for caution on making generalizations from

the data, we believe that the trends reported are large enough that such bias is not significant. In addition, the sources of bias would have to be quite systematic given the size of the dataset.

6. Conclusions

Data were gathered from over 42,000 living alumni, including more detailed information on over 2,100 alumni of the Massachusetts Institute of Technology who had identified themselves as founders of one or more companies during their lifetimes. Although a few respondents started firms in the decades of the 1930s and 1940s, meaningful sample sizes began in the 1950s. Since that time we have witnessed a dramatic growth of the start-up phenomenon among MIT alumni. The sample of founders over this period became much younger at the time of their first entrepreneurial act, gradually included more women over the past 30 years (though the rate at which women are entering entrepreneurship appears not to be keeping pace with their male counterparts), and spread from just U.S. companies formed mostly by U.S. citizens to include firms being founded all over the world by citizens of many countries, all of whom are MIT alumni.

At a broad level we interpret our results as suggesting that the volume of entrepreneurial activity responds to the business and entrepreneurial environment, and that differences in individual characteristics shape the transition to entrepreneurship, both within and across time periods. While the results at the individual level of analysis are intriguing and suggest avenues for further research (some of which are discussed in the prior section), we believe that efforts to better understand the effects of various components of the entrepreneurial business environment on individuals' decisions to start new ventures would also be a very useful direction in this literature. The MIT dataset described in this paper also allows examination of new venture

development over a relatively long time period, which is the subject of our companion paper. At the individual level, we stress the heretofore neglected by-products of research universities as they relate to the entrepreneurial process: training individuals to problem solve and facilitating social processes and a reputation (association with MIT), all of which can become valuable inputs to venture development. As one survey respondent stated: "I look at the MIT experience as training in problem solving. Business is a series of 'problem sets' that must be solved, so MIT is a key training ground."

References

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

Amit, R., Muller, E., Cockburn, I., 1995. Opportunity costs and entrepreneurial activity. Journal of Business Venturing 10 (2), 95-106.

Baron, R.A., 2000. Counterfactual thinking and venture formation: The potential effects of thinking about "what might have been". Journal of Business Venturing 15 (1), 79-91.

Bates, T., 2002. Restricted access to markets characterizes women-owned businesses. Journal of Business Venturing 17 (4), 313-324.

Baumol, W.J., 2004. Education for innovation: Entrepreneurial breakthroughs vs. corporate incremental improvements. NBER Working Paper Series No. 10578

Blanchflower, D.G., Oswald, A.J., 1998. What makes an entrepreneur? Journal of Labor Economics 16 (1), 26-60.

Blau, D.M., 1987. A time-series analysis of self-employment in the United States. The Journal of Political Economy 95 (3), 445-467.

Breslow, N.E., Lubin, J.H., Marek, P., and Langholz, B., 1983. Multiplicative Models and Cohort Analysis. Journal of the American Statistical Association. 78, 1-12.

Buttner, H.E., Moore, D.P., 1997. Women's organizational exodus to entrepreneurship: Self-reported motivations and correlates with success. Journal of Small Business Management 35 (1), 34-46.

Caputo, R.K., Dolinsky, A., 1998. Women's choice to pursue self-employment: The Role of financial and human capital of household members. Journal of Small Business Management 36 (3), 8-17.

Carroll, G.R., Mosakowski, E., 1987. The career dynamics of self-employment. Administrative Science Quarterly 32 (4), 570-589.

Cohen, W., Goto, A., Nagata, A., Nelson, R., Walsh, J., 2002. R&D spillovers, patents and the incentives to innovate in Japan and the United States. Research Policy 31, 1349-1367.

Cox, D.R., 1972. Regression models and life tables. Journal of the Royal Statistical Society, B 34, 187-220.

Dahlstrand, A.L., 1997. Growth and inventiveness in technology-based spin-off firms. Research Policy 26 (3), 331-344.

DeGroof, J.J. and Roberts, E.B., 2004. Overcoming weak entrepreneurial infrastructures for academic spin-off ventures. Journal of Technology Transfer 29 (3/4), 327-352.

DeMartino, R., Barbato, R., 2003. Differences between women and men MBA entrepreneurs: exploring family flexibility and wealth creation as career motivators. Journal of Business Venturing 18 (6), 815-832.

DiGregorio, D., Shane, S., 2003. Why do some universities generate more start-ups than others? Research Policy 32 (2), 209-227.

Dietz, J.S., Bozeman, B., 2005. Academic careers, patents, and productivity: industry experience as scientific and technical human capital. Research Policy 34 (3), 349-367.

Douglas, E.J., Shepherd, D.A., 2000. Entrepreneurship as a utility maximizing response. Journal of Business Venturing 15 (3), 231-251.

Dunn, T., Holtz-Eakin, D., 2000. Financial capital, human capital, and the transition to self-employment: Evidence from intergenerational links. Journal of Labor Economics 18 (2), 282-305.

Etzkowitz, H., 1998. The norms of entrepreneurial science: cognitive effects of the new

university-industry linkages. Research Policy 27 (8), 823-833.

Etzkowitz, H., 2003. Research groups as 'quasi-firms': The invention of the entrepreneurial university. Research Policy 32 (1), 109-121.

Evans, M.D.R., 1989. Immigrant entrepreneurship: Effects of ethnic market size and isolated labor pool. American Sociological Review 54 (6), 950-962.

Gallini, N.T., 2002. The economics of patents: Lessons from recent U.S. patent reform. Journal of Economic Perspectives 16 (2), 131-154.

Gans, J.S., Stern, S., 2003. The product market and the market for "ideas": Commercialization strategies for technology entrepreneurs. Research Policy 32 (2), 333-350.

Gartner, W.B., Shane, S.A., 1995. Measuring entrepreneurship over time. Journal of Business Venturing 10 (4), 283-301.

Gatewood, E.J., Shaver, K.G., Gartner, W.B., 1995. A longitudinal study of cognitive factors influencing start-up behaviors and success at venture creation. Journal of Business Venturing 10 (5), 371-391.

Gimeno, J., Folta, T.B., Cooper, A.C., Woo, C.Y., 1997. Survival of the fittest? Entrepreneurial human capital and the persistence of underperforming firms. Administrative Science Quarterly 42 (4), 750-783.

Gompers, P., Lerner, J., 1999. The venture capital cycle. MIT Press, Cambridge, MA.

Gompers, P., Lerner, J., Scharfstein, D., 2005. Entrepreneurial spawning: Public corporations and the genesis of new ventures, 1986-1999. The Journal of Finance 60 (2), 577-614.

Hart, M.M., Greene, P., Brush, C., Saparito, P., 2001. Patterns of venture capital funding: Is gender a factor. Venture Capital 3 (1), 63-83.

Hayek, F.A., 1945. The use of knowledge in society. The American Economic Review 35 (4),

519-530.

Hellmann, T., 2003. When do employees become entrepreneurs. NBER Working Paper Series http://www.nber.org/~confer/2003/oef03/Hellmann.pdf.

Hsu, D.H., Kenney, M., 2005. Organizing venture capital: The rise and demise of American Research and Capital Corporation, 1946-1973. Industrial and Corporate Change 14, 579-616.

Iyigun, M.F., Owen, A.L., 1998. Risk, entrepreneurship and human-capital accumulation. American Economic Review 88 (2), 454-457.

Jensen, M.C., 1993. The modern industrial revolution, exit and the failure of internal control systems. Journal of Finance 48, 831-880.

Kortum, S., Lerner, J., 1999. What is behind the recent surge in patenting? Research Policy 28, 1-22.

Kortum, S., Lerner, J., 2000. Assessing the contribution of venture capital to innovation. Rand Journal of Economics 31 (4), 674-692.

Landier, A., 2002. Entrepreneurship and the stigma of failure. Mimeo, University of Chicago Graduate School of Business.

Lazear, E.P., 2004. Balanced skills and entrepreneurship. American Economic Review 94 (2), 208-211.

Levesque, M., Minniti, M., in press. The effect of aging on entrepreneurial behavior. Journal of Business Venturing (in press, corrected proof).

McClelland, D.C., 1961. The Achieving Society. D. Van Nostrand Co., Princeton NJ.

Mitchell, R.K., Smith, B., Seawright, K.W., Morse, E.A., 2000. Cross-cultural cognitions and the venture creation decision. Academy of Management Journal 43 (5), 974-993.

Mowery, D.C., Nelson, R.R., Sampat, B.N., 2001. The growth of patenting and licensing by US universities: An assessment of the effects of the Bayh-Dole act of 1980. Research Policy 30 (1), 99-119.

Murphy, K.M., Shleifer, A., Vishny, R.W., 1991. The allocation of talent: Implications for growth. Quarterly Journal of Economics 106 (2), 503-530.

Murray, F., 2004. The role of academic inventors in entrepreneurial firms: Sharing the laboratory life. Research Policy 33 (4), 643-659.

Nelson, R.R., 1996. The Sources of Economic Growth, Harvard University Press, Cambridge, MA.

Nicolaou, N., Birley, S., 2003. Social networks in organizational emergence: The university spinout phenomenon. Management Science 49 (12), 1702-1725.

Oliver, A.L., 2004. Biotechnology entrepreneurial scientists and their collaborations. Research Policy 33 (4), 583-597.

Owen-Smith, J., 2003. From separate systems to a hybrid order: Accumulative advantage across public and private science at Research One universities. Research Policy 32 (6), 1081-1104.

Owen-Smith, J., Powell, W.W., 2001. To patent or not: Faculty decisions and institutional success at technology transfer. Journal of Technology Transfer 26 (1-2), 99-114.

Owen-Smith, J., Powell, W.W., 2004. Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community. Organization Science 15 (1), 5-21.

Parhankangas, A., Arenius, P., 2003. From a corporate venture to an independent company: A base for a taxonomy for corporate spin-off firms. Research Policy 32 (3), 463-481.

Powell, W.W., Koput, K.W., Smith-Doerr, L., 1996. Interorganizational collaboration and the

locus of innovation: Networks of learning in biotechnology. Administrative Science Quarterly 41, 116-145.

Roberts, E.B., 1991. Entrepreneurs in High Technology: Lessons from MIT and Beyond, Oxford University Press, New York NY.

Roberts, E.B., 2004. A perspective on 50 years of the engineering management field. IEEE Transactions on Engineering Management 51 (4), 398-403.

Sarasvathy, D.K., Simon, H.A., Lave, L., 1998. Perceiving and managing business risks: Differences between entrepreneurs and bankers. Journal of Economic Behavior and Organization 33 (2), 207-225.

Saxenian, A.L., 1999. Silicon Valley's New Immigrant Entrepreneurs, Public Policy Institute of California, San Francisco CA.

Saxenian, A.L., 2002. Local and Global Networks of Immigrant Professionals in Silicon Valley, Public Policy Institute of California, San Francisco CA.

Schumpeter, J.A., 1943. Capitalism, Socialism and Democracy, Harper and Row, New York.

Shane, S., 1995. Is the independent entrepreneurial firm a valuable organizational form? Academy of Management Journal 110-113.

Shane, S., 2000. Prior knowledge and the discovery of entrepreneurial opportunities. Organization Science 11 (4), 448-469.

Shane, S., 2002. Selling university technology: Patterns from MIT. Management Science 48 (1), 122-137.

Shane, S., Khurana, R., 2003. Bringing individuals back in: The effects of career experience on new firm founding. Industrial and Corporate Change 12 (3), 519-543.

Sine, W.D., David, R.J., 2003. Environmental jolts, institutional change, and the creation of

entrepreneurial opportunity in the US electric power industry. Research Policy 32 (2), 185-207.

Sorensen, J.B., 2005. Closure vs. exposure: Assessing alternative mechanisms in the intergenerational inheritance of self employment, MIT Sloan School of Management Working Paper.

Stuart, T.E., Ding, W.W., 2005. When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. American Journal of Sociology, provisional accept.

Stuart, T., Sorenson, O., 2003. The geography of opportunity: Spatial heterogeneity in founding rates and the performance of biotechnology firms. Research Policy 32 (2), 229-253.

Utterback, J.M., 1994. Mastering the Dynamics of Innovation, Harvard Business School Press, Cambridge MA.

Utterback, J.M., Meyer, M., Roberts, E., Reitberger, G., 1988. Technology and industrial innovation in Sweden: A study of technology-based firms formed between 1965 and 1980. Research Policy 17 (1), 15-26.

VentureOne, I., 2000. Venture Edge, VentureOne Press, San Francisco.

Vohora, A., Wright, M., Lockett, A., 2004. Critical junctures in the development of university high-tech spinout companies. Research Policy 33 (1), 147-175.

von Hippel, E., 2005. Democratizing Innovation, MIT Press, Cambridge MA.

Zucker, L.G., Darby, M.R., Brewer, M.B., 1998. Intellectual human capital and the birth of U.S. biotechnology enterprises. American Economic Review 88 (1), 290-306.

Figure 1

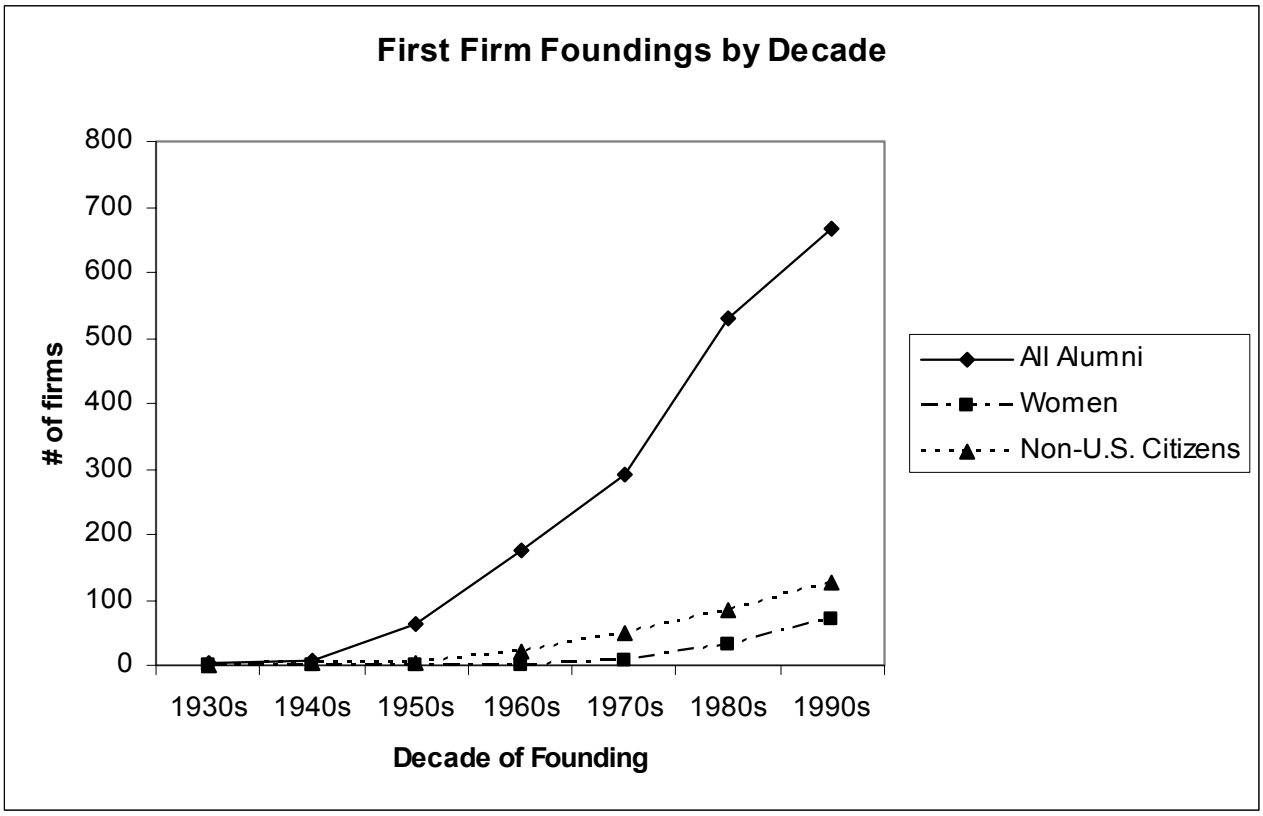
First Firm Foundings by Decade
800
700
600
500
400
300
200
100
0
# of firms
1930s
1940s
1950s
1960s
1970s
1980s
1990s
Decade of Founding
All Alumni
Women
Non-U.S. Citizens

Figure 2

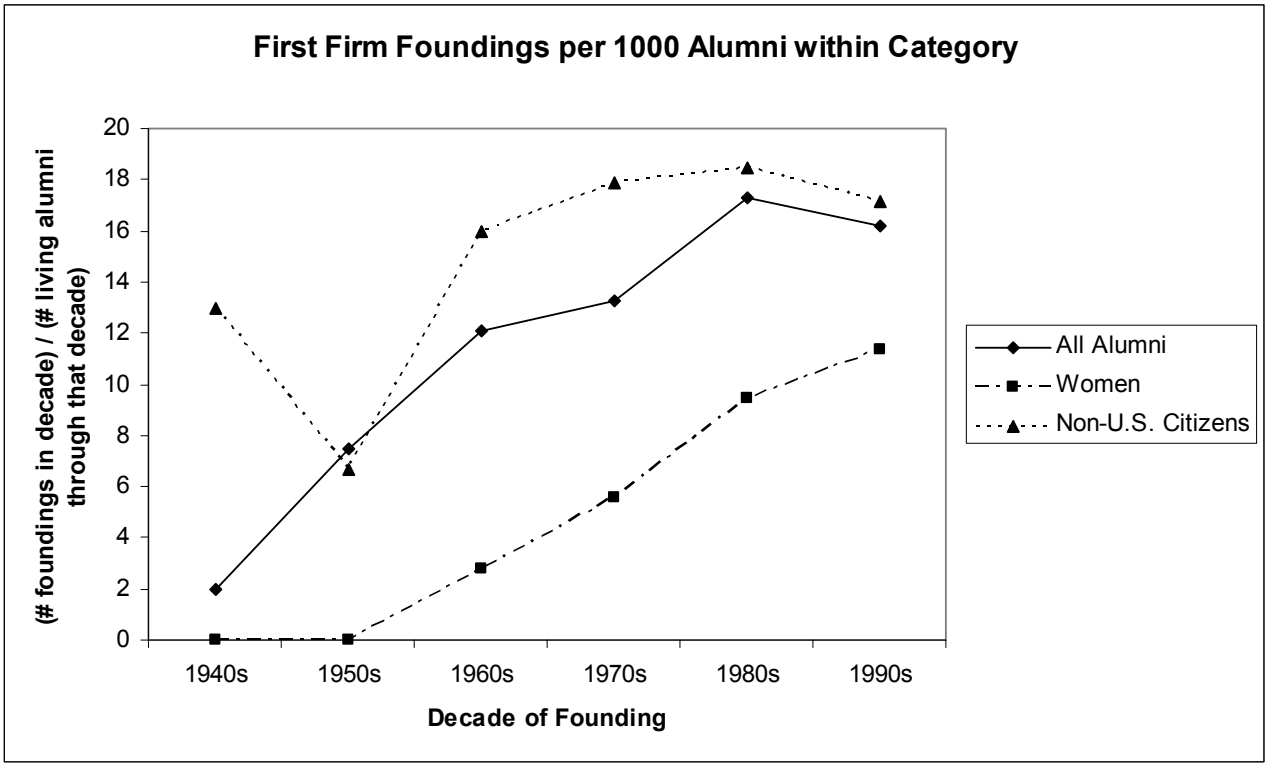
First Firm Foundings per 1000 Alumni within Category
(# foundings in decade) / (# living alumni through that decade)
20
18
16
14
12
10
8
6
4
2
0
1940s
1950s
1960s
1970s
1980s
1990s
Decade of Founding
All Alumni
Women
Non-U.S. Citizens

Figure 3

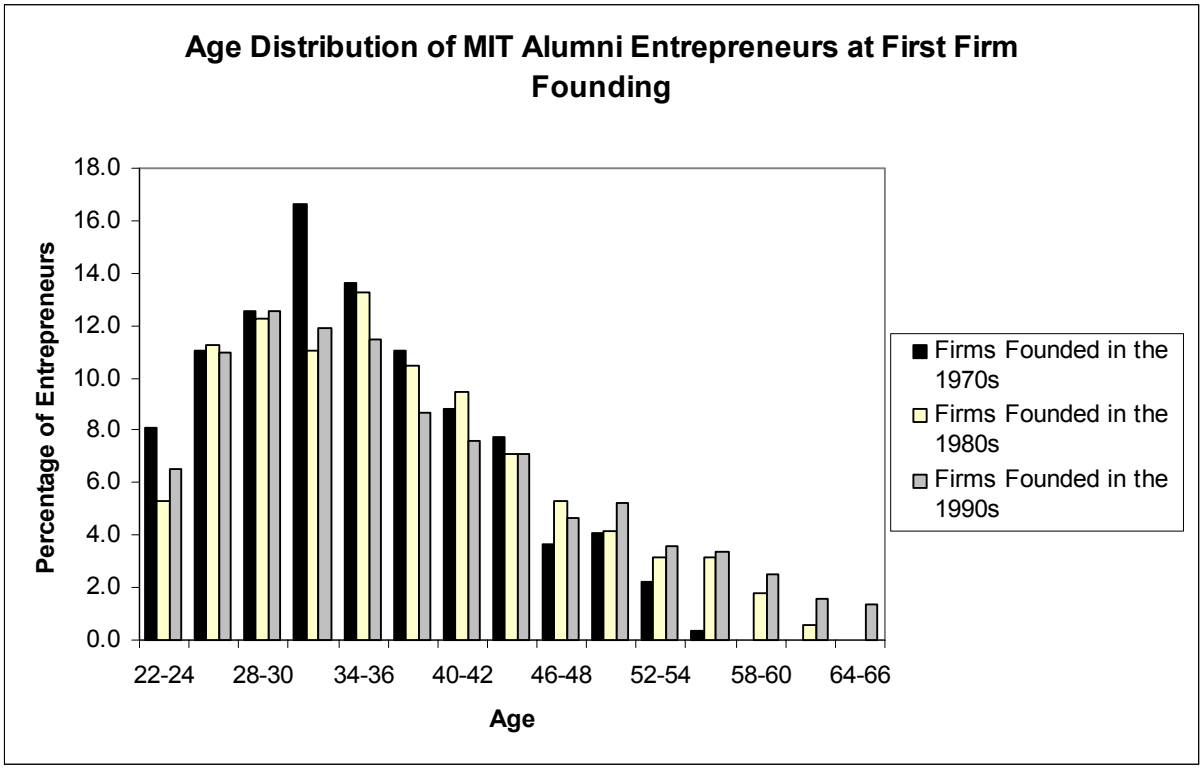
Age Distribution of MIT Alumni Entrepreneurs at First Firm Founding
Percentage of Entrepreneurs
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
22-24
28-30
34-36
40-42
46-48
52-54
58-60
64-66
Age
Firms Founded in the 1970s
Firms Founded in the 1980s
Firms Founded in the 1990s

Figure 4

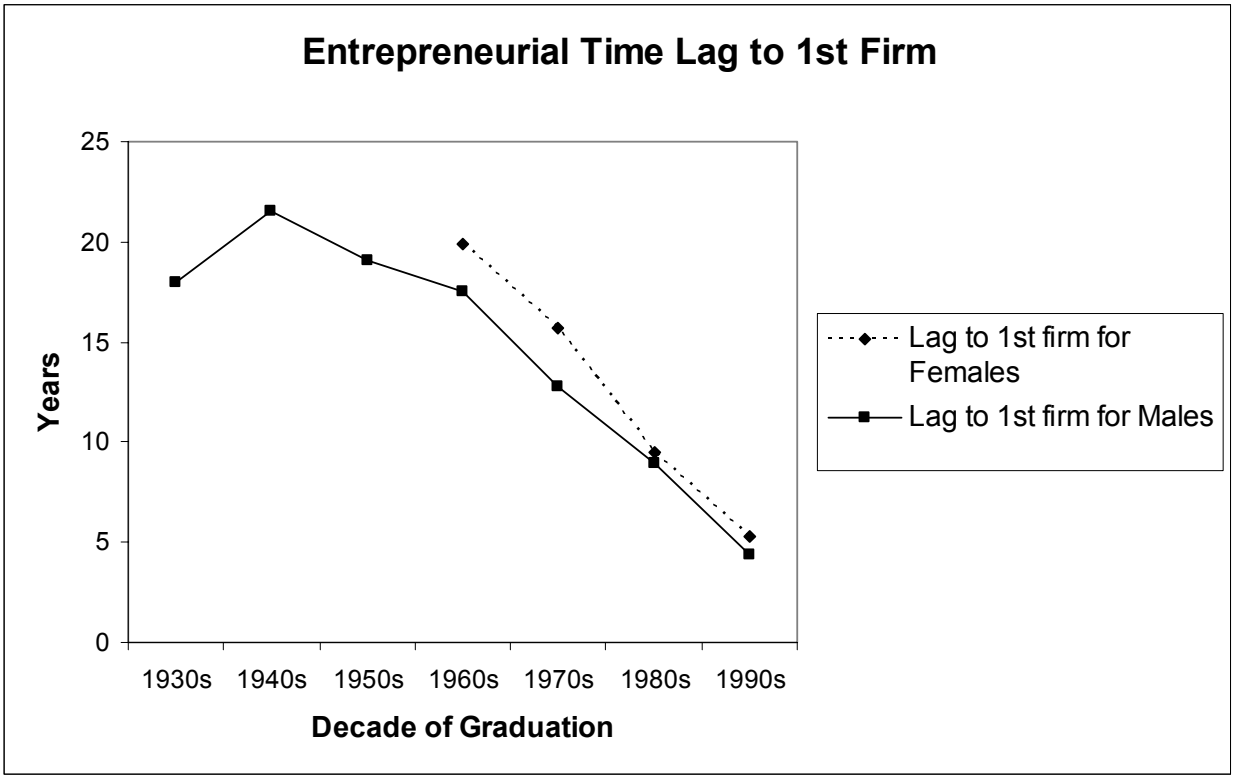
Entrepreneurial Time Lag to 1st Firm
25
20
15
10
5
0
Years
1930s
1940s
1950s
1960s
1970s
1980s
1990s
Decade of Graduation
Lag to 1st firm for Females
Lag to 1st firm for Males

Figure 5

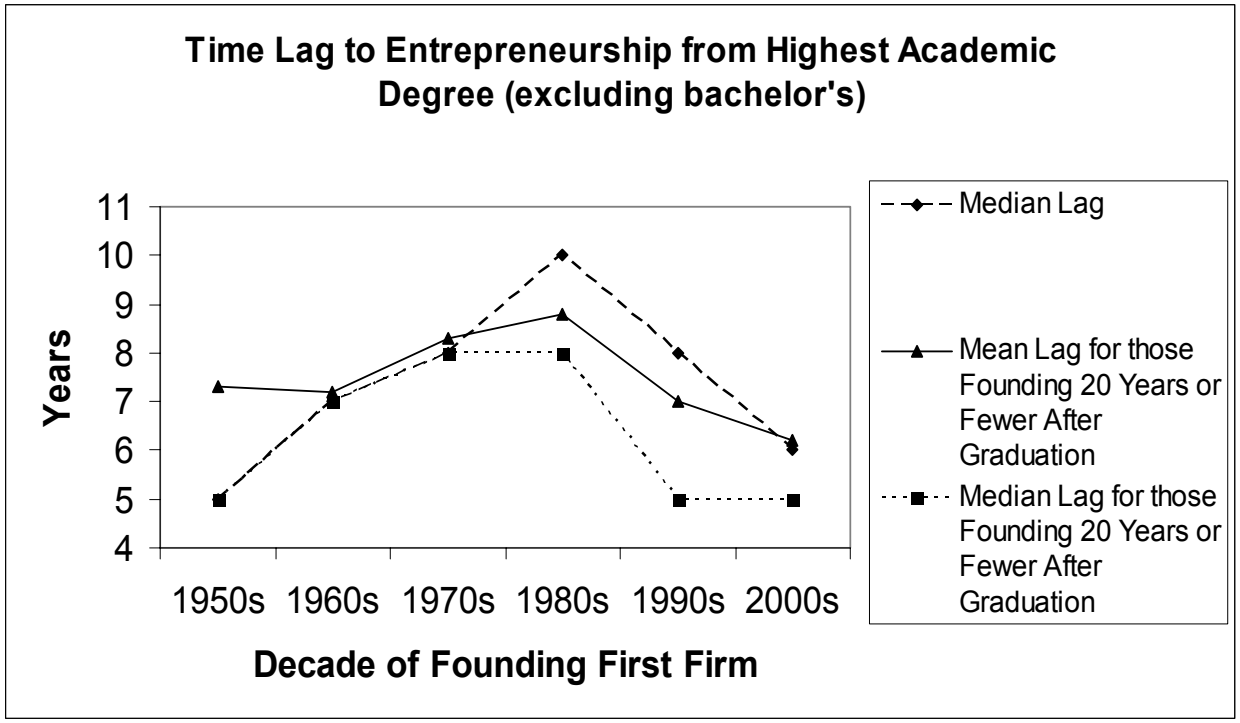
Time Lag to Entrepreneurship from Highest Academic Degree (excluding bachelor's)
Years
11
10
9
8
7
6
5
4
1950s
1960s
1970s
1980s
1990s
2000s
Decade of Founding First Firm
Median Lag
Mean Lag for those Founding 20 Years or Fewer After Graduation
Median Lag for those Founding 20 Years or Fewer After Graduation

Figure 6

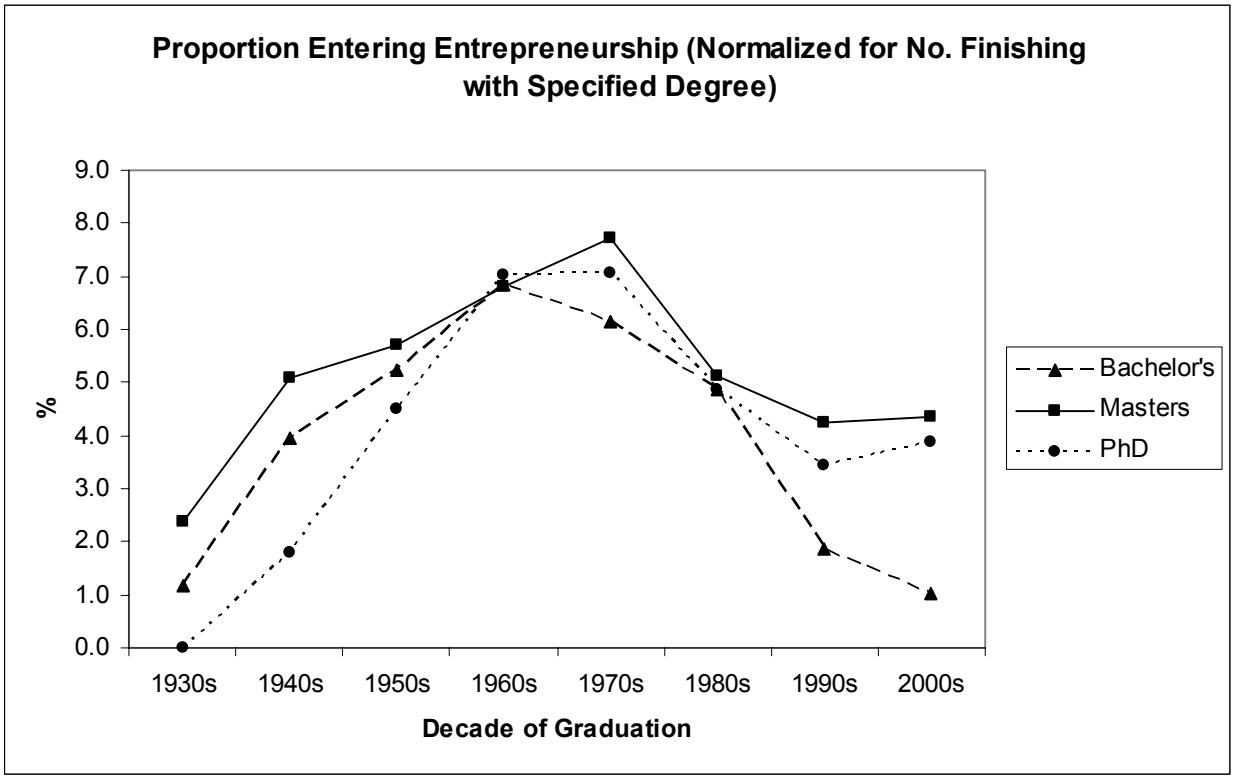
Proportion Entering Entrepreneurship (Normalized for No. Finishing with Specified Degree)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
%
1930s
1940s
1950s
1960s
1970s
1980s
1990s
2000s
Decade of Graduation
Bachelor's
Masters
PhD

Figure 7

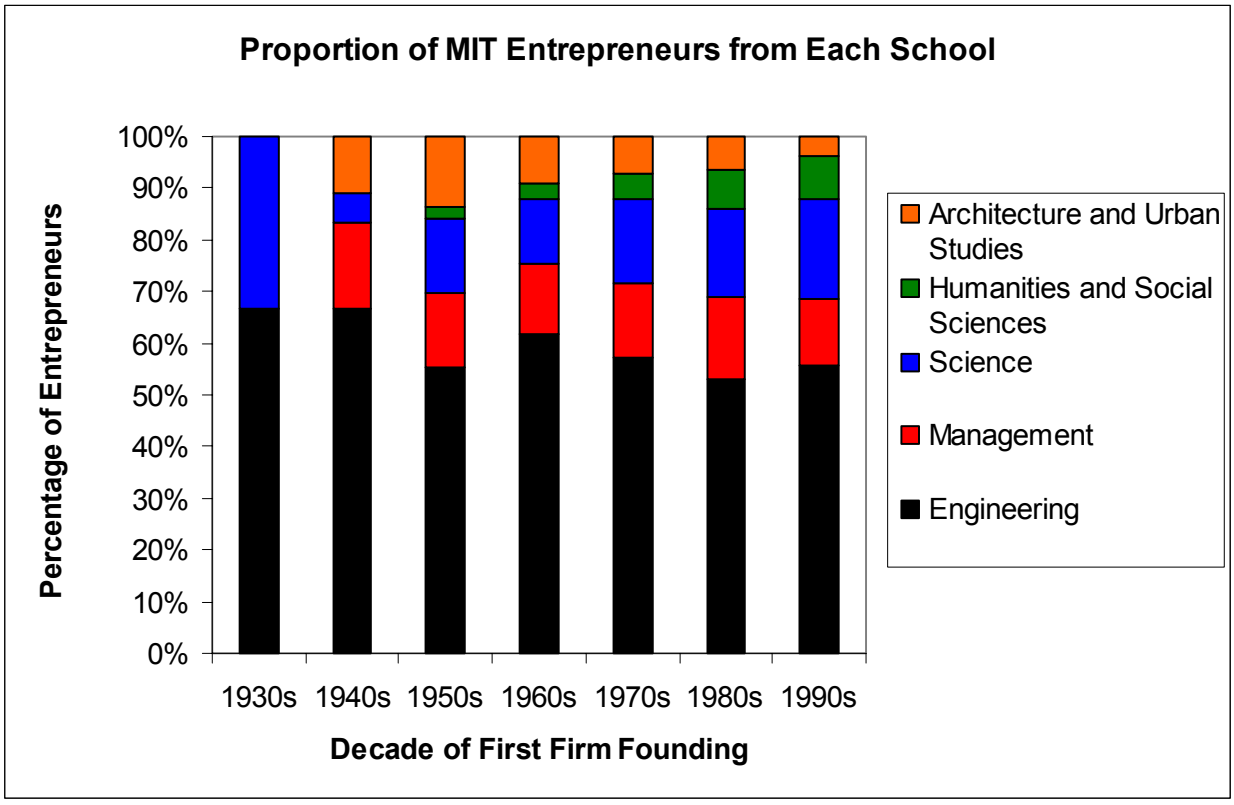
Proportion of MIT Entrepreneurs from Each School
Percentage of Entrepreneurs
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1930s
1940s
1950s
1960s
1970s
1980s
1990s
Decade of First Firm Founding
Architecture and Urban Studies
Humanities and Social Sciences
Science
Management
Engineering

Figure 8

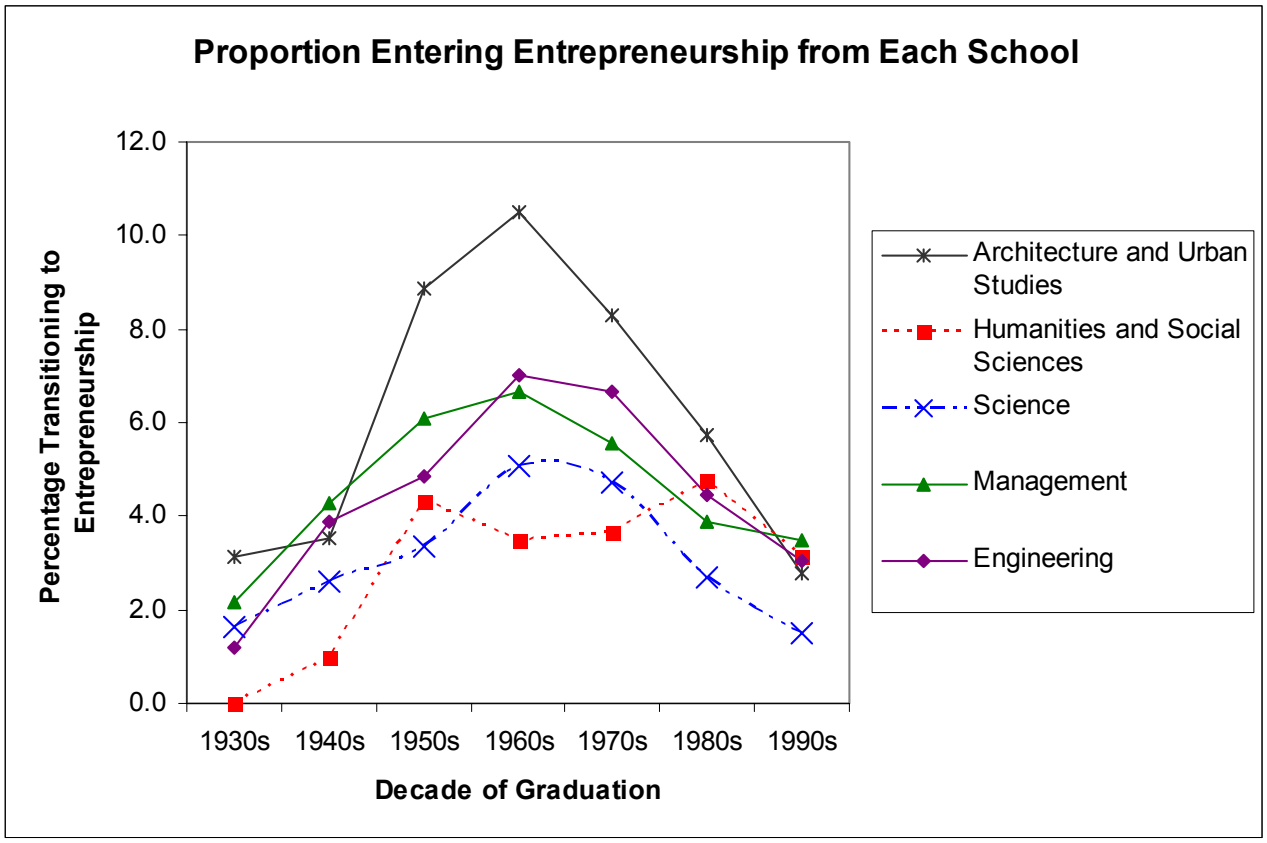
Proportion Entering Entrepreneurship from Each School
Percentage Transitioning to Entrepreneurship
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1930s
1940s
1950s
1960s
1970s
1980s
1990s
Decade of Graduation
Architecture and Urban Studies
Humanities and Social Sciences
Science
Management
Engineering

Figure 9

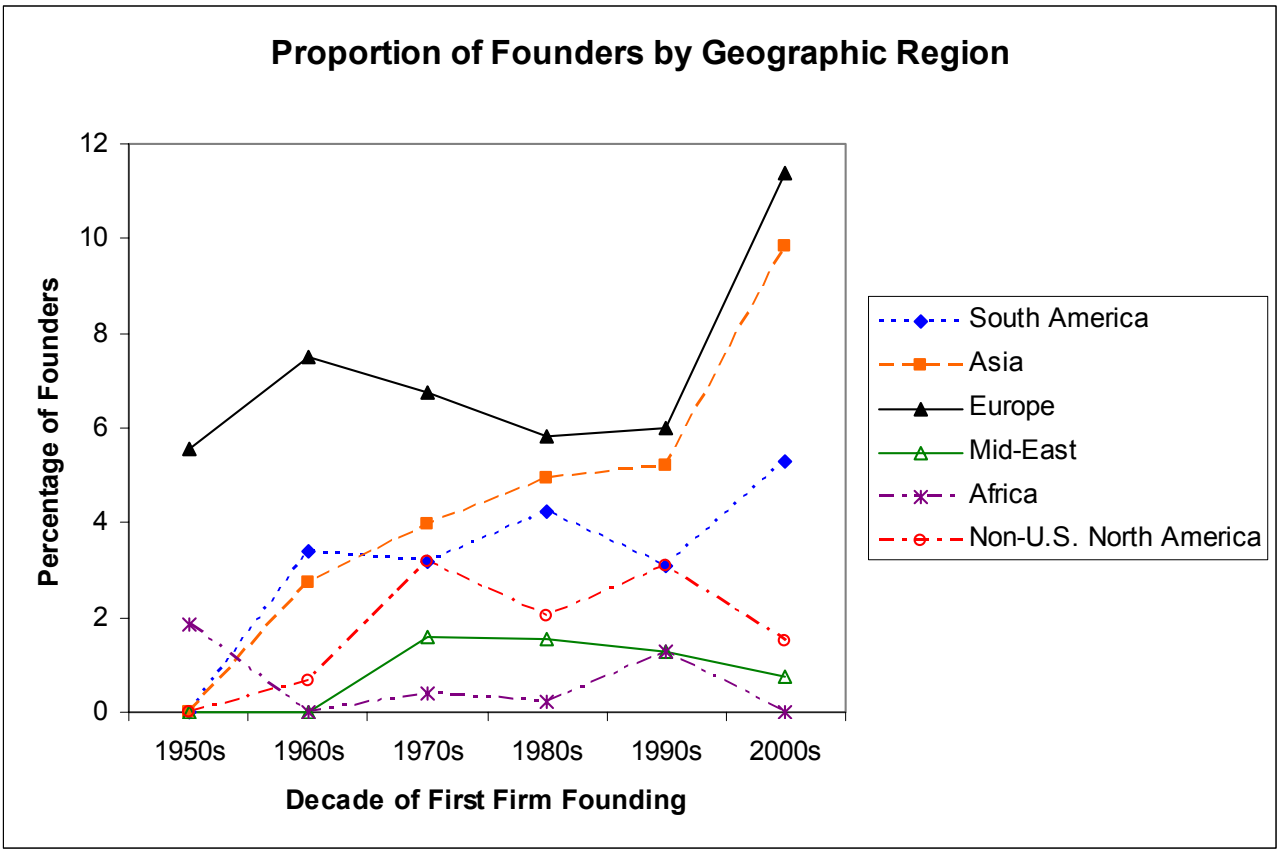
Proportion of Founders by Geographic Region
Percentage of Founders
12
10
8
6
4
2
0
1950s
1960s
1970s
1980s
1990s
2000s
Decade of First Firm Founding
South America
Asia
Europe
Mid-East
Africa
Non-U.S. North America

Table 1
Trends in Graduates Becoming Entrepreneurs and Timing of the Transition to Entrepreneurship

Panel A - Median Age at First Firm Founding (years)					
Decade of Graduation	**1950s**	**1960s**	**1970s**	**1980s**	**1990s**
All	40.5	39	35	32	28
Non-U.S. Citizens	38	35.5	36.5	32	29
Women	42	41	40	35	29
Panel B - Proportion of Entrepreneurs by Final Degree (%)					
Decade of First Firm Founding	**1950s (N=60)**	**1960s (N=167)**	**1970s (N=284)**	**1980s (N=507)**	**1990s (N=653)**
Bachelor's	53.2	44.0	41.3	46.8	25.3
Masters	36.4	36.0	40.3	38.4	56.2
Doctorates	10.4	20.0	18.4	14.9	18.5
Panel C - Proportion of Founders for Certain Academic Departments (%)					
Decade of First Firm Founding	**1950s (N=54)**	**1960s (N=147)**	**1970s (N=252**	**1980s (N=448)**	**1990s (N=620)**
EE & CS degrees	20.4	26.5	18.7	25.4	22.7
Management degrees	16.7	14.3	13.5	13.8	15.8
Life Sciences degrees	0.0	2.7	4.0	4.9	4.7

Table 2
Summary Statistics and Variable Definitions

VARIABLE	DEFINITION	MEAN	SD
Individual-level measures			
First start-up founded	Year in which first firm was founded (censored if not observed by 2003)	1985.49	12.26
Graduation year	Year of MIT graduation	1973.91	14.98
Male	Dummy = 1 if the individual is male	0.86	0.34
Academic major	Set of dummies for academic major: engineering (54%), management (14%), social science (5%), architecture (3%), and natural science (the excluded category)		
Country of origin	Set of dummies for country of citizenship: Latin America (2%), Asia (7%), Europe (7%), Middle East (1%), Africa (1%) or North America (the excluded category)		
Year-level measures			
First firm foundings	Number of first firms found	25.53	25.94
Number of graduates (t-1)	Number of individuals in the MIT graduating class in the prior year	559.66	320.00
Patents issued (t-1)	Number of U.S. patents issued in the prior year (‘000s)	66.37	35.38
Venture capital disbursements (t-1)	Total disbursements made by venture capital firms in the prior year ($B)	3.99	13.88
Recessionary economy (t-1)	Dummy = 1 if the U.S. economy was in recession in the prior year as determined by the NBER	0.29	0.46
Gross domestic product (t-1)	Gross domestic product of the U.S. economy in the prior year ($B)	4053.54	2796.37
Inflation rate (t-1)	Inflation rate of the U.S. economy in the prior year (%)	3.34	4.12
NY stock exchange market cap. (t-1)	Total market capitalization of the New Stock Exchange in the prior year ($)	1.84e+9	3.14e+9

Table 3
Entrepreneurship Cox Hazard Rate Regressions
(Individual level of analysis)

	Dependent Variable = *First start-up founded* (subjects start being at risk at year of birth) Note: reported coefficients are hazard ratios			
Independent Variables	**(3-1)**	**(3-2)**	**(3-3)**	**(3-4)**
Graduation year	1.022***			1.024***
	(0.002)			(0.002)
Male	1.980***			2.050***
	(0.193)			(0.202)
Engineering major		1.495***		1.543***
		(0.096)		(0.100)
Management major		1.411***		1.230**
		(0.121)		(0.106)
Social science major		1.129		1.095
		(0.150)		(0.146)
Architecture major		2.246***		2.190***
		(0.240)		(0.236)
Latin American citizen			1.936***	1.547***
			(0.271)	(0.219)
Asian citizen			0.824*	0.626***
			(0.095)	(0.073)
European citizen			1.025	0.915
			(0.102)	(0.092)
Middle Eastern citizen			1.781***	1.320
			(0.412)	(0.306)
African citizen			1.453	1.084
			(0.440)	(0.329)
Log likelihood	-14592.44	-14618.12	-14656.67	-14520.16
Number of observations	10,780	10,780	10,780	10,780

Note: 1,626 failures; 555,996 years at risk; ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 4
Entrepreneurship Cox Hazard Rate Regressions by Birth Cohort
(Individual level of analysis)

	Dependent Variable = *First start-up founded* (subjects start being at risk at year of birth) Note: reported coefficients are hazard ratios			
	Birth year: 1912-1937	Birth year: 1938-1948	Birth year: 1949-1959	Birth year: 1960-1979
Independent Variables	**(4-1)**	**(4-2)**	**(4-3)**	**(4-4)**
Graduation year	0.984**	0.969***	0.970***	1.010
	(0.007)	(0.009)	(0.009)	(0.010)
Male	1.837	1.229	1.855***	3.038***
	(0.933)	(0.290)	(0.302)	(0.455)
Engineering major	1.329*	1.573***	1.634***	1.275**
	(0.197)	(0.197)	(0.207)	(0.157)
Management major	1.495**	1.986***	1.757***	1.034
	(0.294)	(0.332)	(0.305)	(0.177)
Social science major	1.147	0.999	1.383	1.105
	(0.393)	(0.288)	(0.314)	(0.280)
Architecture major	3.553***	2.598***	3.134***	1.225
	(0.706)	(0.685)	(0.578)	(0.328)
Latin American citizen	2.157*	3.165***	1.876***	0.901
	(0.895)	(0.794)	(0.473)	(0.259)
Asian citizen	0.632	1.255	0.609**	0.613***
	(0.321)	(0.318)	(0.131)	(0.110)
European citizen	1.281	0.703	0.960	1.095
	(0.261)	(0.176)	(0.197)	(0.189)
Middle Eastern citizen	3.614*	#	2.043**	1.060
	(2.588)		(0.693)	(0.380)
African citizen	1.344	0.384	0.615	1.612
	(0.957)	(0.385)	(0.616)	(0.618)
Log likelihood	-2805.30	-3131.14	-3147.90	-3390.09
Number of observations	2,540	2,706	2,695	2,839
Failure events	365	406	410	445
Time at risk	175,949	153,359	126,728	99,960

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively. # denotes insufficient data for estimation.

Table 5
First Firm Foundings Negative Binomial Regressions, 1930-2003
(Year level of analysis)

	Dependent Variable = *Number of First Firm Foundings*			
Independent Variables	**(5-1)**	**(5-2)**	**(5-3)**	**(5-4)**
Number of graduates (t-1)	0.003***	0.004***	0.001**	0.002***
	(0.000)	(0.000)	(0.000)	(0.001)
Patents issued (t-1)	0.002***			0.002***
	(0.000)			(0.000)
Venture capital disbursements (t-1)		0.060***		0.026***
		(0.013)		(0.009)
Recessionary economy (t-1)			0.188	0.275*
			(0.159)	(0.148)
Gross domestic product (t-1)			6.26e-4***	4.32e-4***
			(9.97e-5)	(9.98e-5)
Inflation rate (t-1)			-0.005	-0.010
			(0.023)	(0.022)
NY stock exchange market cap. (t-1)			1.99e-10***	-3.68e-10***
			(6.19e-11)	(6.97e-11)
Constant	-0.886***	0.353	-0.241**	-1.053***
	(0.300)	(0.286)	(0.237)	(0.357)
Log likelihood	-247.51	-266.35	-234.43	-226.01
Number of observations	72	72	71	71
Pseudo R-squared	0.17	0.11	0.20	0.23

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.