

Inside or Outside the IP-System? Business Creation in Academia

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Abstract

Research and public policy on academic entrepreneurship in the United States is based on the assumption that the entrepreneurial activity of U.S. academics is accurately represented by efforts of faculty to commercialize inventions that they have disclosed to university administrators and that, in most cases, have been patented. In this paper, we analyze a sample of 11,572 university professors, representative of the entire population of academics affiliated to Carnegie I and II United States universities, and we find that a large part of the academic entrepreneurship activities occur outside the IP-system. In particular, a large proportion of businesses started by academics (about 2/3) are not based on disclosed and patented inventions. Moreover, we show that individual characteristics, departmental and organizational affiliation, as well as working time allocation, of academics starting business outside the IP-system are systematically different from those who have started businesses on disclosed and patented inventions. These findings have implications for research on academic entrepreneurship, as well as technology transfer policies.

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1. Introduction

Research and public policy on academic entrepreneurship in the United States is based on the assumption that the entrepreneurial activity of U.S. academics is accurately represented by efforts of faculty to commercialize inventions that they have disclosed to university administrators. Virtually all studies of this phenomenon, and all efforts to develop related policies, examine only entrepreneurial activities generated as a result of a formal disclosure process that occurs within the intellectual property system (IP-system) put in place by university administrators. Casual and anecdotal evidence, however, suggest that a number of entrepreneurial activities by academics occur outside of this system (Rothaermel et al., 2007). This anecdotal evidence leads us to ask: are the entrepreneurial activities of academics that take place outside the formal IP system different from those conducted within the system?

Differences in the types of entrepreneurial activities that occur inside and outside the formal IP-system, and the differences in many characteristics of the individuals and their institutional affiliations of those involved with them, if unacknowledged by researchers and policy makers, may have major consequences. First, researchers might systematically underestimate the depth and breadth of entrepreneurial activities by academics. Moreover, different types of university researchers in different technical fields and institutions may be more likely to engage in outside-the-formal-system entrepreneurial activities than engage in entrepreneurial activity through formal IP-channels. As a result, policies aimed at stimulating only formal IP-based entrepreneurial activity might fail to influence entire categories of individuals and entire academic disciplines, thus hampering efforts to generate more entrepreneurial activity from universities.

Our empirical evidence is based on a survey of a sample of 11,572 university professors, representative of the population of 58,646 academics affiliated with Carnegie I and II United States universities employed in National Research Council tracked disciplines. We show that a large share of academic entrepreneurship occurs outside the IP-system and that the academics who undertake this activity differ from the ones who engage in academic entrepreneurship within the formal IP-system. In particular, our findings show that approximately two-thirds of the businesses started by academics are not based on disclosed and patented inventions. Moreover, we show that the individual characteristics and departmental and organizational affiliation of academics who have started businesses outside the IP-system differ systematically from those who have started businesses on disclosed and patented inventions. Researchers whose entrepreneurial activities are

based on inventions disclosed to universities younger and more likely to be female than academics whose entrepreneurial outputs are not based on inventions disclosed to universities. We also show that research efforts highly predict entrepreneurship inside the IP-system, but teaching efforts significantly affect entrepreneurial activities that occur outside the formal IP system. Finally, academics whose entrepreneurial activities are based on disclosed inventions tend to be affiliated with a different set of departments than academics whose entrepreneurial activities are not based on disclosed inventions. In particular, academics in bio-sciences are more likely to engage in entrepreneurial activities based on disclosed inventions, while academics in social sciences and, perhaps more interestingly, in engineering, are disproportionately likely to engage in entrepreneurial activities not based on such inventions.

These findings have implications for efforts to develop and test theories of academic entrepreneurship, as well as efforts to develop technology transfer policies. An accurate understanding of academic entrepreneurship requires researchers to capture the entire range of efforts by academics to profit commercially from their scholarly activities. A focus solely on the commercial activities that result from patented inventions underestimates the importance of academic entrepreneurship and leads, potentially, to misunderstandings about why academics engage in entrepreneurial activity, the types of academic efforts that faculty seek to commercialize, and the types of academics who engage in this activity, among other things.

From a policy perspective, the findings also have important implications. If policy makers believe that academic entrepreneurship is a valuable activity that they seek to encourage, then they need to have accurate estimates of its frequency, who engages in it and why they do so. Lack of information, or inaccurate information, can lead policy makers to formulate policies that do not encourage adequate amounts of academic entrepreneurship or do not take proper advantage of such activities.

The remainder of this paper is organized as follows. In Section 2, we characterize the entrepreneurial activities that occur inside and outside the formal university IP-system. In Section 3 we describe our sample, the survey instrument and the data we collected. Section 4 is devoted to the data analysis, while Section 5 concludes. All tables and figures are gathered in the appendices.

2. Technology transfer activities inside and outside the IP-system

Over the past thirty years, there has been an increasing interest in the commercialization of technologies developed within universities. Academic entrepreneurship has come to be considered as a natural stage in the evolution of the modern university, which takes economic development as one of its goals, in addition to the more traditional mandates of education and research (Rothaermel et al., 2007). Moreover, the direct involvement of academic scientists in commercial activities is thought to mitigate problems in transferring academic knowledge to the private sector and to motivate researchers to undertake projects of greater economic relevance (Gibbons et al., 1994, Zucker and Darby, 1995, Ezkowitz, 2004).

Academic entrepreneurship manifests itself in many different forms, such as patenting, licensing of inventions, and new business creation. As a consequence, policy makers and university administrators have increasingly put effort in developing a set of mechanisms to support these activities. In the United States, for example, policy makers have enacted legislation to stimulate universities to undertake more industrially relevant research, including the 1980 Bayh-Dole Act and the 1986 Federal Technology Transfer Act. Similar initiatives have been undertaken more recently in Europe and Japan (Geuna et al., 2003).

During the last decade, the level of academic entrepreneurship has increased dramatically. In the United States, the number of new U.S. patent applications by academic institutions has risen from less than 3,000 in 1996, to more than 10,000 in 2006. The number of new start-up companies formed to commercialize university research has grown from less than 200 in 1996 to almost 500 in 2006, and the number of licenses and options executed by academic institutions has increased from slightly more than 2,000 in 1996, to slightly more than 4,000 in 2006. Finally, gross license income received by academic institutions has increased from less than \$400 million in 1996, to more than \$1.2 billion in 2006 (AUTM, 2006).

[Figures 1, 2, 3 and 4 about here]

However, all of the commercial activities reported to have increased over the past decade are those that occur within the formal IP-system. In fact, the vast majority of the existing literature on academic entrepreneurship focuses on the formal IP-system, which, as described by Mowery et al. (2002), is a process that starts with an invention disclosed to a TTO, which becomes a

patented piece of intellectual property that is licensed, either to an established company or to an entrepreneur seeking to found a new company. Scholars have examined all of the different parts of this process, from invention disclosures (Friedman and Silberman, 2003; Thursby and Thursby, 2005), patenting (Henderson et al., 1998; Hall et al., 2001; Mowery et al., 2002; Mowery and Ziedonis, 2002; Coupe, 2003; Sampat et al., 2003; Bercovitz and Feldman, 2008), to licensing (Jensen and Thursby, 2001; Jensen et al., 2003), to the creation of new businesses to exploit university-assigned intellectual property (Nerkar and Shane, 2003; Markman et al., 2004).

This focus on university-assigned IP is understandable, given the paucity of data on academic entrepreneurship outside of the formal IP-system. However, it does raise several questions that researchers and policy makers ought to consider. First, how common is academic entrepreneurship? The focus on academic entrepreneurship through the formal IP-system might greatly understate the total amount of academic entrepreneurship and the frequency with which professors engage in it. Prior research suggests this, arguing that many forms of academic entrepreneurship, such as consulting and collaborations, occur outside the formal IP-system (Mansfield, 1995; Cohen et al., 1998; Jensen and Thursby, 2001; Beath et al., 2003; Dechenaux et al., 2007; Jensen et al., 2007).¹ Second, does academic entrepreneurship take the same form if it occurs within and outside the formal IP-system? Research suggests that academic entrepreneurship might take very different forms when university assigned IP is not a for it because different industries make very different use of formal intellectual property rights (Klevorick et al., 1987, Cohen et al., 2000). Third, are different technical fields equally likely to engage in academic entrepreneurship through the formal IP-system? Because the value of patents differs across industries, scholars in the biological and chemical sciences, where patents tend to be strong, might be more likely to engage in academic entrepreneurship through the formal IP-system than scholars in engineering and the social sciences, where patents are less important. Fourth, do different types of academics engage in academic entrepreneurship inside and outside the formal IP-system? To some extent, whether to undertake commercial activities inside or outside the formal IP-system is an individual choice that might depend on personal characteristics, such as age, experience and tenure in academia. More senior academics, for example, might have developed more of a personal reputation and therefore be more

¹ Somewhat in contrast with the empirical literature that tends to be focused on very specific types of commercial activities by academics, some of the theoretical literature that has developed in recent years explains entrepreneurial activities by academics in ways not predicated on the university Intellectual Property rights (Thursby et al., 2007, Aghion et al., 2008, Lacetera, 2008).

able than their more junior colleagues to commercialize knowledge that they have developed in the absence of a patent that demonstrates the value of the knowledge. To date, however, no comprehensive evidence has been collected on the extent of academic entrepreneurship that occurs inside and outside the IP-system. The analysis that follows is aimed at closing this gap.

3. Data and Research Design

3.1 The sample

This study is based on a survey that was administered to 58,646 tenured or tenure track faculty members and post-doctoral researchers at all Carnegie I and II categorized universities (except the researchers' home university) in National Research Council (NRC) tracked departments, during the second half of 2007. The 26 NRC departments are within the four disciplinary areas of Engineering, Biological and Medical Sciences, Social and Human Sciences, and Mathematics, Physics and Statistics.²

The survey was administered electronically, with the survey sent to email addresses that were obtained from university websites during the first half of 2007. Participation was entirely voluntary and no financial reward was given for participation. Four follow-up electronic messages were sent to non-respondents to encourage their response. Respondents on leave (medical or sabbatical) were excluded from the sample. At the close of data collection, 11,572 usable responses were received, yielding a 20 percent response rate. This response rate is consistent with that of studies based on survey data, in which participation is voluntary (Lee et al., 2001)

3.2 The questionnaire

The questionnaire encompassed three main sections. In the first section we gathered demographical information such as gender, age, academic rank, years of experience in academia (at the current and at any other universities), and departmental affiliation. The second section asked questions about the respondent's number of publications, the amount and the source of research funding received, the level of interaction with institutions and industry, as well as the time allocation of academic work during the academic year 2006-2007. The third section collected information about the commercialization of a respondent's academic research. They were asked, in particular, whether they had disclosed inventions, whether they held US patents (as inventors or assignees), how many businesses they have started based on their research, and how many of those businesses

² A full list of department is reported in table 1

were based on a patent. As a consequence, we could also derive whether a respondent had also started businesses not based on formal IP.³

3.3 Additional data sources

In addition to the information collected through our survey, we gathered secondary information on the respondents' universities. Information was gathered from three main sources: The Carnegie Classifications Data File 2008; the Association of University Technology Managers (AUTM) U.S. Licensing Activity Survey: FY2006; and the US News and World Report: Americas Best Colleges. The collected data include information about university ownership (public/private); size (bachelor's degree total, doctoral degree total, total full-time research faculty and non-faculty research staff); R&D expenditures (total "science & engineering" R&D expenditures and total "non-science & engineering" R&D expenditures), location (region and whether urban or rural); technology-transfer support mechanisms and technology-transfer outputs (existence of a TTO, starting year of technology transfer program, number of start-up companies formed, new US patent applications filed and licenses/options executed); and the university's quality rank as defined by US News and World Report.⁴

3.4 Data Description

Table 3 provides descriptive statistics on the characteristics of the respondents. About 78 percent of the respondents were males. The average and median age is approximately 49 years old. Only a small minority of respondents was younger or older. About 70 percent of the respondents hold tenured positions, with at least ten years of experience in academia at the time of participation in the survey.

[Table 2 about here]

The average respondent had published 53 articles at the time of the survey, and had raised about \$285,000 of research funds in the year 2006-2007. As table 4 shows, however, there were respondents with hundreds of publications and millions of dollars of research funds. On average, respondents report that about 6.5 percent of their research funds come from for-profit companies.

³ A further section asked questions of only to those academics that had started a company. We gathered information about the year of establishment of the business, the individuals role at start-up and the current status of the business. We do not examine information from this section of the survey in this paper. We define "starting a business" as the establishment of a new for-profit company related to the respondent's university work..

⁴ A list of university-level variables is reported in table 8.

This reported share is very close to the National Science Foundation (NSF) estimate of industry funding of academic research (NSF, 2005).

As for the time allocation of the academics during 2006-2007, interactions with industry people was limited to, on average, 2.4 percent of the respondents' non-administrative time, while teaching and research occupy, respectively, 35.3 percent and 26.2 percent of that time. As table 5 shows, writing grants, managing PhD students and attending conferences account for the remaining 45 percent of the time.

[Tables 3 and 4 about here]

About 21percent of respondents are affiliated with engineering departments, 19percent to biological and medical sciences, 33 percent with social and human sciences and 27 percent to mathematics, physics and statistics. More that 70 percent of respondents are affiliated with public universities, and 12percent of them serve as professors in top 20 universities. Approximately 97 percent of the respondents work at a university with a T*O and in 77 percent of the cases it was established after the passage of the Bayh-Dole act.

We also explored the commercial activities undertaken by the respondents. As reported in table 6, the most frequent commercial activity was the disclosure of inventions; followed by patenting and licensing of inventions and, finally, by the starting of companies. However, most of the interviewed academics do not engage in commercial activities; only about 36 percent of the sample has undertaken any of these activities during their academic careers.

[Table 5 about here]

As table 6 shows, the distribution of commercial activities is highly skewed, with a few outliers who are heavily engaged in these activities. Because of this high skewness (and because of possible report and recall errors and biases), in the following analyses we rely on dichotomous variables, considering whether an individual has been involved in any of the activities or not. Thus, our different measures of commercial activities are the following dummy variables: whether the respondents have disclosed an invention, whether they have patented, whether they have licensed a patented invention, whether they have started a business based on a patent, and whether they have started a business not based on a patent.

3.5 Reliability and sample selection

Because this research relies heavily on respondents to provide the data, common method variance may lead to spurious associations between some of the variables of interest. To deal with that problem, the questionnaire was designed to maximize the separation between predictor and dependent variables (Podsakoff et al., 2003).

A second, major concern was that 20 percent of the sample that responded to the survey might not be representative of the overall population.⁵ In order to address this issue, we drew a random sample of 1,000 individuals among the non-respondents, and collected information about their gender, age, department affiliation and university. To the extent that the propensity to engage in academic entrepreneurship is related to the academic field of a researcher, his or her university affiliation, age and gender, a comparison of the survey respondents (along the previously mentioned observable dimensions) with the random sample of 1,000 non-respondents will inform us about the representativeness of our sample. In order to assess the presence of selectivity, we therefore performed probit regressions in which the dependent variable was an indicator of whether or not the individual responded to the survey. For regressors we included dummy variables for the subject's gender, age, academic field, and university. Economically sizable coefficient estimates of these variables would indicate that the sample of respondents is not highly representative. Table 6 reports the regression results, and Figure 5 plots the predicted probabilities of being in the sample for the respondents and the non-respondents. Given the high number of observations, it is not surprising that some coefficient estimates are precise and therefore are significantly different from zero in statistical terms. Their size, however, is very small in most cases, and several parameter estimates are not significantly different from zero, suggesting, again, that sample selection is not a major issue in our research. Nevertheless, to ensure that response bias did not affect our data, in the following analysis, we correct for any amount of selectivity through inverse probability weighting (Wooldridge, 2002).

[Table 6 about here]

[Figure 5 about here]

⁵ For example, faculty with a greater experience in (or propension to) commercializing their research might have a greater incentive to complete the survey. Vice versa, professors who are engaged in a higher number of activities beyond their “traditional” ones might have less time to respond. Younger respondents, being less likely to be tenured (or even tenure track), might have lower incentives to “divert” their attention from their research by answering a questionnaire.

4. Data Analysis

4.1 The “Outside the System” academic entrepreneurs

At first glance, the focus of researchers on invention disclosures as the definition of the sampling frame for academic entrepreneurship appears to be reasonable. As shown above, the most common commercial activity that we explored was the disclosure of inventions (which about 25 percent of the sample engaged in), followed by patenting (which about 19 percent of the sample engaged in) and then by starting a new firm (which about 16 percent of the sample engaged in). However, this initial conclusion is contradicted by information on the types of new companies that the academics have started. The majority of academics in the sample who started new firms did not do so to exploit a patented invention. Overall, 1,226 respondents (about 11 percent of the sample) started a business that was not based on a patented invention, as compared to 682 (about 5 percent of the sample) who started a business based on a patented invention.

Furthermore, the population of academics starting businesses not on a patented invention does not overlap with academics operating inside the IP-system. Table 7 provides such evidence. It shows the frequency of each entrepreneurial activity across the respondents, the number of cases in which a given activity is the only one undertaken by a respondent, and the instances of combinations of two activities. The majority of academics who have disclosed an invention, patented, licensed and started a business based on a patent have performed at least one of these other activities, but those who have started a business not based on a patent tend not to have engaged in any of these other activities.

[Table 7 about here]

Figure 6 offers a visual representation of the difference between the two groups of academic entrepreneurs. The figure shows that 958 academics have established a company not based on a formal piece of intellectual property and have not performed any of the other commercial activities. On the contrary, only 170 academics have started a business not on patent, but also, over their careers, have disclosed an invention and filed at least one patent. Only 99 academics have both started a business not on a patent and undertaken the entire set of IP-based entrepreneurial activities (disclosed an invention, filed at least one patent and started a business based on patent).

[Figure 6 about here]

Business creation inside and outside the formal IP-system, therefore, appears to be following markedly different processes. The finding that a vast majority of academics have started businesses not based on formal IP suggests that a non-negligible number of academic entrepreneurs have gone

largely unnoticed in the scholarly literature and the policy community. While important, this fact is not sufficient, however, to argue that different analytical and policy instruments need to be employed in order to understand and support this form of knowledge transfer. To do that, we need evidence of systematic differences between the academic entrepreneurship that takes place inside and outside the formal IP-system. In the remainder of this section, we provide that evidence through bivariate analyses and multivariate regression models.

4.2 Bivariate analyses

As a first step, we report a set of bivariate analyses relating a number of individual, departmental and university characteristics of the respondents to their entrepreneurial activities. The results show several differences in individual level characteristics. Figure 7 shows some limited gender differences in the tendency to start businesses based on patents and not based on patents. Figure 8 shows somewhat greater trends for the effect of age. The data show that academics seem to avoid entrepreneurial endeavors early in their careers, in ways consistent with career cycle models of scientists (Levin and Stephan, 1991; Thursby et al., 2007),⁶ the relationship between age and entrepreneurial activities is not the same for starting non-IP based businesses. Junior academics are more involved in academic entrepreneurship that is not based on patented inventions than that based on patented inventions.

[Figures 7 and 8 about here]

Figure 9 shows the distribution of respondents across the four disciplinary areas conditional on starting a business on a patent and not on a patent.⁷ As table shows, the differences are striking. While respondents who have started a business through IP-based mechanisms are clustered in bio-medical disciplines, such as biology and chemistry, non-IP based activities are more prevalent in engineering related areas, such as mechanical and civil engineering, as well as in the social sciences.

Other patterns also emerge when we look at the institutions where the respondents are employed, as described in figures 10 and 11. In particular, researchers who start a business on a

⁶ Since we just have a cross section, however, we cannot test properly for age or tenure profiles.

⁷ We have identified four disciplinary areas. In the first one, labeled Engineering, we have included Aerospace Engineering, Civil Engineering, Computer and Electrical Engineering, Industrial and Manufacturing Engineering, Materials Science and Mechanical Engineering. In the second one, labeled Biological and Medical Sciences, we have included Agricultural Sciences, Biology and Biochemistry, Biomedical Engineering, Chemical Engineering, Chemistry, Geology, Marine Sciences, Neuroscience and Pharmacy. In the third one, labeled Social and Human Sciences, we have included Anthropology and Sociology, Ecology and Evolution, Economics and Agricultural Economics, Geography, History and other humanities, Political Science and Psychology. In the last one, labeled Mathematics, Physics and Statistics, we have included Computer Science, Mathematics, Physics and Astronomy and Statistics.

patent are much more likely to be found in highly ranked schools, while the opposite is true for entrepreneurs who start businesses not based on a patent.

[Figures 9, 10 and 11 about here]

In figures 12 and 13, we explore the allocation of the respondents' time across different activities. We find that academics who have started businesses based on patents spend less time on research and teaching than the average respondent, which is consistent with a trade-off between academic and commercial activities. However, the time spent on research and teaching by academic entrepreneurs who started businesses not based on patents does not differ from that of a random respondent.

[Figures 12 and 13 about here]

In sum, academic entrepreneurship that occurs through the formal IP-system appears to be correlated with certain individual and institutional characteristics, and with the researchers' approaches to their academic activities, in ways different from academic entrepreneurship that occurs outside of this system. In order to assess which of these differences represent stable, underlying patterns, we turn now to the multivariate regressions analyses that we performed.

4.3 Regression Analysis

Table 9 reports three sets of regressions. In columns (1) to (4), we assess how a series of covariates correlate with the probability of starting a business based on formal IP (all else constant), in comparison with the overall sample of respondents. In column (5) to (8), we repeat the same exercise on the same sample, with the outcome of interest being the start of a business not based on formal IP. Finally, in columns (9) to (12), we limit the sample to those who have started a business, and analyze how our regressors correlate to the probability of starting a business on based on a patent as opposed to starting a business not based on a patent. In each subset of analyses, the model in the first column includes only individual characteristics such as gender and age. The second column adds variables related to the scientific productivity of the researchers (as expressed by the log of cumulative publications), the value of the research funds that they had obtained (in terms of log of value of research funds available in 2006-2007), the allocation of their time across different activities, the sources of their funding, and dummy variables for their disciplinary areas. In the third column, we add school fixed effects to control for differences across universities. In the fourth column, we "unpack" the school fixed effects by substituting for them with a series of time-invariant school characteristics that previous researchers have found to be associated with academic

entrepreneurship, such as year of establishment, location, US News and World Report ranking, overall R&D expenditure in 2006, presence or absence of a technology transfer office (TTO), whether the TTO was established before and after the Bayh-Dole act was passed (in 1981), and whether a University is public or not. By “unpacking” the fixed effects, we can assess whether specific characteristics of universities correlate systematically with different types of academic entrepreneurship.

Regressions are estimated as linear probability, OLS models, with Huber-White robust standard errors.⁸ In Section 3.4, we reported that we found some statistically significant – though quantitatively small – selectivity in the sample of respondents, based on a series of observable characteristics (such as gender and age). The analyses reported in table 9 are corrected to account for such a potential selection bias. Each observation is weighted though an inverse probability procedure (Wooldridge, 2002), using the probit regressions that predict the likelihood of being a respondent (as reported in table 2). Weights for each observation are given by the inverse of the predicted values of the same observation in the selection regression.⁹

The regression analyses confirm most of the descriptive evidence, and point to a number of additional findings. Four sets of variables show robust, statistically significant and economically substantive correlations with our outcome variables. First, the coefficient estimates for the dummy variables for the age categories indicate that academic entrepreneurs who started their businesses not based on patents tend to be younger than those who started their businesses based on patents, although the inclusion of the variables for publication records and research funding appears to attenuate the age effect. Second, the evidence shown in the bivariate analysis of the trade-off between commercial activities on the one hand, and research and teaching on the other, for just patent-based academic entrepreneurship holds in the multivariate analysis.

Third, the multivariate analysis confirms the differences in departmental affiliation of the two different forms of academic entrepreneurship. In the regressions, the biological and medical sciences emerge as the disciplinary areas where starting businesses based on patents is more likely to occur. Business started not on a patent, instead, are more likely to occur in departments related to social sciences and behavioral studies.

⁸ Probit and logit regressions convey very similar results. We report linear regressions results here, because they are more immediate to interpret.

⁹ For example, if an observation is much more likely to be in the sample of respondents as opposed to one of the 1,000 random observations against which we compared the respondents, then that observation receives a lower weight in the regressions.

Fourth, the set of dummy variables for the different universities is jointly significant, but only marginally so. Moreover, in the multivariate analysis, the only robust university-level variables that were statistically significant were those related to the geographic location of the institution.

[Table 9 about here]

5. Discussion and conclusion

The evidence analyzed in this paper is mostly descriptive and its cross-sectional nature precludes us from drawing strong causal implications. However, the size of our sample and its representativeness across schools and departments, as well as the different empirical specifications implemented, lend support to the key finding of this study: a sizeable portion of academic entrepreneurs engage in commercial activity that lies outside the formal university IP-system, leading estimates of academic entrepreneurship based on activities within the formal IP-system to understate the amount of this activity. Moreover, the academics that start non-patent based companies are not well represented by their colleagues who start businesses based on their patents.

These findings have implications for our efforts to understand academic entrepreneurship. Because scholarly efforts to date have focused largely on academic entrepreneurs who start businesses to exploit patented inventions, our theories for why and how this activity occurs are incomplete. Moreover, our efforts to develop and test theories of academic entrepreneurship likely would yield better results if they were based on samples of all academic entrepreneurs, rather than just those that exploit patented inventions. Second, we need studies of the broader range of academic entrepreneurship to generalize to the phenomenon. The extent to which the large body of literature on academic entrepreneurship that has been developed over the past thirty years can be generalized might be quite constrained, given the differences between entrepreneurs who exploit university assigned patents and those that do not. For example, previous studies have investigated the presence of trade-offs between traditional academic activities and commercial activities (Agrawal and Henderson, 2002; Goldfarb et al., 2006; Azoulay et al., 2006; Breschi et al., 2007). Our results suggest that these trade-offs might be limited to academic efforts to start companies based on their patents.

Our findings also have implications for public policy and for the management of research commercialization activities by universities. Policies aimed at reinforcing intellectual property rights by universities, such as the stream of legislative interventions started with the Bayh-Dole act in 1980

and the administrative infrastructure built up in response to those changes, are targeting only a part of the entrepreneurial activities that academics undertake, while leaving out an important subset of them. Moreover, efforts to facilitate the entrepreneurial activities of academics through activities of technology transfer offices, as is currently the practice, are failing to help a sizeable portion of academic entrepreneurs whose entrepreneurial activities occur outside the formal IP system that TTOs are part of. As a result, university efforts to harness academic entrepreneurship for purposes of creating private wealth and enhancing social welfare might be underperforming vis-à-vis their potential.

Furthermore, our findings have implications for how university administrators might manage university technology commercialization. For instance, the study shows that patent based start-ups are distributed across fewer disciplines than non-patent based start-ups, which highlights a problem of the focus on patent-based academic entrepreneurship. University administrators tend to focus their commercialization efforts on a small number of academic fields, under the assumption that they are where “the action lies”. This creates problems administrators concerned with university contributions to economic development or resource acquisition. By focusing on patent-based entrepreneurial activity, university administrators are falsely concentrating their resources on a small number of fields and ignoring much potential entrepreneurial activity.

Finally, our contribution has also managerial implications. For instance, they suggest the importance of informal relationships between firms and academic researchers. Several observers have argued that, in order to take full advantage of the potential of university technology transfer, firms should develop both formal and informal mechanisms for interacting with university researchers (Grimpe and Hussinger, 2008). Our results support this argument, as we show that a relevant facet of academic entrepreneurship occurs outside formal IP-channel. Therefore, R&D managers might benefit from developing relationships with researchers, rather than interacting with universities solely through their TTOs.

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A. Tables

Table 1: Departments by disciplinary areas

Disciplinary areas	National Research Council tracked departments
Engineering	Aerospace Engineering Civil Engineering Computer and Electrical Engineering Industrial and Manufacturing Engineering Materials Science Mechanical Engineering
Biological and Medical Sciences	Agricultural Sciences Biology and Biochemistry Biomedical Engineering Chemical Engineering Chemistry Geology Marine Sciences Neuroscience Pharmacy
Social and Human Science	Anthropology and Sociology Ecology and Evolution Economics and Agricultural Economics Geography History and other humanities Political Science Psychology
Mathematics, Physics and Statistics	Computer Science Mathematics Physics and Astronomy Statistics

Table 2: Descriptive Statistics

Gender	N	Percent
Female	2,565	22.17
Male	9,007	77.83
Total	11,572	100.00
Age		
20-29	174	1.54
30-39	2,681	23.67
40-49	3,106	27.42
50-59	3,176	28.03
60-69	1,896	16.74
70-79	294	2.60
Total	11,327	100.00
Academic rank		
Professor with Endowed Chair	972	8.40
Full Professor	4,607	39.80
Associate Professor with Tenure	2,608	22.54
Associate Professor without Tenure	357	3.09
Assistant Professor	2,693	23.27
Lecturer	333	2.88
Other	2	0.02
Total	11,572	100.00
Years in academia		
From 0 to 5	1,689	14.67
From 6 to 10	2,024	17.57
From 11 to 15	1,540	13.37
From 16 to 20	1,524	13.23
From 21 to 25	1,313	11.40
More than 26	3,427	29.76
Total	11,517	100.00
Technological area		
Engineering	2,466	21.31
Biomedical Sciences	2,291	19.80
Social Sciences	3,835	33.14
Physics and Mathematics	2,980	25.75
Total	11,572	100.00

Table 3: Descriptive statistics, (con't): Research Output

Research activities	N	Mean	Std. Dev.	Min	Max
Number of academic articles published	11,398	53.30	94.14	0	6,080
Total value of research funding (06-07)	10,980	285,817	1,121,758	0	64,000,000

Table 4: Descriptive statistics (Con't): Time allocation and sources of funding

Time allocation of academic work (% of 2006-2007 time)		Percent
Teaching		35.31
Researching		26.17
Meeting industry people		2.37
Writing grants		11.74
Managing PhD students		18.49
At conferences		5.91
Total (N=8,536)		100.00
Source of research funding (% of 2006-2007 research funds)		
Profit company		6.55
Government agency or other public source		61.28
Foundation or other non-profit organization		9.6
Your institution		22.56
Total (N=8,351)		100.00

Table 5: Entrepreneurial activities

Entrepreneurial activities	N	Mean	Std. Dev.	Min	Max
Number of disclosures	11,311	1.42	6.08	0	350
Number of U _s patents issued	11,302	0.95	4.40	0	131
Number of licenses	11,200	0.35	2.23	0	70
Number of new businesses started	10,825	0.25	0.90	0	52
Number of new businesses started on patent	11,157	0.09	0.41	0	10

Table 6: Probit regression of the probability of being a respondent

	Dep. Var: 1 if respondent, 0 if non respondent
Male	-0.00597 (0.01)
Age: 30-39	-0.0196 (0.03)
Age: 40-49	-0.029 (0.03)
Age: 50-59	-0.0201 (0.02)
Age: 60-69	-0.0491* (0.03)
Age: 70-79	-0.130*** (0.05)
Dept: Bio-Science	0.00806 (0.01)
Dept: Social and Human behavior	0.00301 (0.01)
Dept: Physics and Math	-0.00786 (0.01)
University fixed effects	YES
Observations	12,009
Pseudo R-squared	0.04
chi-squared test on all parameters	253.86
prob>chi2	0.00
chi-squared test on Discipline dummies	5.26
prob>chi2	0.15
chi-squared test on University dummies	190.13
prob>chi2	0.21

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Probit model, marginal effects reported

Table 7: Joint frequency of entrepreneurial activities

Variable	Tot	Only activity	In conjunction with			
			Disclosure	Patent	License	New business on patent
Disclosure	2,950	762				
US Patent issued	2,166	106	1,822			
License (on US patent)	1,146	8	998	1,071		
New business on patent	682	23	610	560	358	
New business not on patent	1,266	771	432	314	172	138

Variable	Correlation table			
	Disclosure	Patent	License	New business on patent
Disclosure	1			
US Patent issued	0.67	1		
License (on US patent)	0.47	0.64	1	
New business on patent	0.37	0.41	0.37	1
New business not on patent	0.07	0.06	0.05	0.07

Table 8: Variables included in regression models

Variable	Description
Bus on Pat	Dummy: 1 if at least one business started on patent.
Bus not on Pat	Dummy: 1 if at least one business started on patent not on patent.
Male	Dummy: 1 if respondent is male.
Age (6 Categories)	Dummies: Age: 20-29 (baseline); Age: 30-39; Age: 40-49; Age: 50-59; Age 60-69; Age: 70-79.
Ln(Number of academic articles)	Ln(Number of academic articles).
Ln(Value research funds 06-07)	Ln(Total value of research funding (06-07)).
Time: % in teaching (06-07)	% of 06-07 time in teaching.
Time: % in researching (06-07)	% of 06-07 time in researching.
Time: % in meeting industry (06-07)	% of 06-07 time in meeting industry people.
Research funds: % from profit company (06-07)	% of 06-07 research founding from profit company.
Dept (4 Categories)	Dummies: Engineering (baseline); Biological & Medical Sciences; Social & Human Sciences; Mathematics, Physics & Statistics.
Uni Age (3 Categories)	Dummies: University Age: 1-99 (baseline); University Age: 100-200; University Age >200.
Regional (6 Categories)	Dummies: Middle States (baseline); New England; North Central; Northwest; Southern; Western.
Localization (4 Categories)	Dummies: City (baseline), Town, Rural, Not Assigned.
USRank (4 Categories)	Dummies: UsRank:1-20; UsRank: 21-50; UsRank: 51-100; UsRank: >100.
Ln(Rd expenses in the university)	Ln(R&D expenses in the university).
TTO: Presence	Dummy: 1 if university has TTO.
TTO: Post Bayh-Dole	Dummy: 1 if TTO has been established after Bayh-Dole (1981).
Public university	Dummy: 1 if university is public.

Table 9- Regression results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Biz. on pat	Biz. on pat	Biz. on pat	Biz. on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.
Male	0.0504*** (0.00)	0.0164*** (0.01)	0.0156** (0.01)	0.0145** (0.01)	0.0555*** (0.01)	0.0438*** (0.01)	0.0456*** (0.01)	0.0436*** (0.01)	0.156*** (0.03)	-0.017 (0.04)	-0.0247 (0.05)	-0.0281 (0.05)
Age: 30-39	0.00719 (0.01)	-0.0257 (0.02)	-0.0306 (0.02)	-0.0102 (0.02)	0.0206 (0.01)	0.0327 (0.02)	0.0333 (0.02)	0.0522*** (0.02)	-0.0518 (0.18)	-0.235 (0.16)	-0.209* (0.11)	-0.239* (0.14)
Age: 40-49	0.0392*** (0.01)	-0.0285 (0.02)	-0.0336 (0.02)	-0.0157 (0.02)	0.0719*** (0.01)	0.0814*** (0.02)	0.0779*** (0.02)	0.101*** (0.02)	-0.0654 (0.18)	-0.305* (0.16)	-0.255** (0.11)	-0.309** (0.14)
Age: 50-59	0.0379*** (0.01)	-0.0353 (0.02)	-0.0389* (0.02)	-0.0236 (0.02)	0.104*** (0.01)	0.115*** (0.02)	0.116*** (0.03)	0.135*** (0.02)	-0.13 (0.18)	-0.345** (0.16)	-0.308*** (0.11)	-0.356** (0.14)
Age: 60-69	0.0349*** (0.01)	-0.0288 (0.02)	-0.0354 (0.02)	-0.0159 (0.02)	0.115*** (0.02)	0.133*** (0.03)	0.135*** (0.03)	0.157*** (0.02)	-0.149 (0.18)	-0.344** (0.16)	-0.315*** (0.11)	-0.352** (0.15)
Age: 70-79	0.0578*** (0.02)	0.01 (0.04)	0.0124 (0.04)	0.0252 (0.04)	0.0693*** (0.02)	0.116*** (0.04)	0.110** (0.05)	0.130*** (0.04)	0.0236 (0.19)	-0.199 (0.18)	-0.106 (0.14)	-0.148 (0.17)
Ln(Number of academic articles)		0.0301*** (0.00)	0.0283*** (0.00)	0.0319*** (0.00)		-0.00968* (0.01)	-0.00806 (0.01)	-0.00765 (0.01)		0.0928*** (0.02)	0.0893*** (0.02)	0.0954*** (0.02)
Ln(Total value of research funding (06-07))		0.00744*** (0.00)	0.00699*** (0.00)	0.00719*** (0.00)		0.0103*** (0.00)	0.0108*** (0.00)	0.0128*** (0.00)		0.0107 (0.01)	0.00619 (0.01)	0.00668 (0.01)
Time: % in teaching (06-07)		-0.000642*** (0.00)	-0.000724*** (0.00)	-0.000557** (0.00)		0.000746** (0.00)	0.000455 (0.00)	0.000553 (0.00)		-0.00410*** (0.00)	-0.00378*** (0.00)	-0.00408*** (0.00)
Time: % in researching (06-07)		-0.000761*** (0.00)	-0.000819*** (0.00)	-0.000717*** (0.00)		0.000146 (0.00)	0.000104 (0.00)	0.000407 (0.00)		-0.00566*** (0.00)	-0.00480*** (0.00)	-0.00552*** (0.00)
Time: % in meeting industry people (06-07)		0.00757*** (0.00)	0.00764*** (0.00)	0.00810*** (0.00)		0.0118*** (0.00)	0.0115*** (0.00)	0.0106*** (0.00)		-0.00245 (0.00)	-0.00183 (0.00)	-0.000561 (0.00)
Research funds: % from profit company (06-07)		0.00146*** (0.00)	0.00152*** (0.00)	0.00146*** (0.00)		0.000716** (0.00)	0.000724** (0.00)	0.000750** (0.00)		0.00158*** (0.00)	0.00229*** (0.00)	0.00167*** (0.00)
Dept: Bio-Science		-0.00591 (0.01)	-0.00203 (0.01)	-0.00455 (0.01)		-0.0837*** (0.01)	-0.0846*** (0.01)	-0.0919*** (0.01)		0.141*** (0.04)	0.152*** (0.04)	0.155*** (0.04)
Dept: Social and Human behaviour		-0.0310** (0.01)	-0.0320** (0.01)	-0.0306** (0.01)		-0.02 (0.02)	-0.0174 (0.02)	-0.0291* (0.02)		-0.170*** (0.04)	-0.164*** (0.05)	-0.149*** (0.04)
Dept: Physics and Math		-0.0468*** (0.01)	-0.0465*** (0.01)	-0.0477*** (0.01)		-0.0494*** (0.02)	-0.0484*** (0.02)	-0.0534*** (0.02)		-0.0375 (0.05)	-0.0537 (0.05)	-0.034 (0.05)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Biz. on pat	Biz. on pat	Biz. on pat	Biz. on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.
Uni: age100-200				-0.00915 (0.01)				-0.000548 (0.02)				-0.05 (0.05)
Uni: age>200				-0.0000295 (0.02)				0.00587 (0.02)				-0.0765 (0.07)
Regional: New England				-0.00804 (0.02)				-0.0109 (0.02)				-0.034 (0.07)
Regional: North Central				0.00541 (0.01)				0.0132 (0.01)				-0.00331 (0.05)
Regional: Northwest				0.0484** (0.02)				0.0179 (0.02)				0.135* (0.07)
Regional: Southern				-0.013 (0.01)				0.0102 (0.01)				-0.0563 (0.05)
Regional: Western				-0.00354 (0.02)				0.0387* (0.02)				-0.0832 (0.07)
Localization: Town				-0.0181* (0.01)				0.0077 (0.01)				-0.0604 (0.05)
Localization: Rural				0.00808 (0.02)				0.049 (0.03)				0.0242 (0.10)
Localization: Not assigned				0.00484 (0.04)				0.0316 (0.06)				0.0286 (0.13)
UsRank: 21-50				-0.00733 (0.02)				0.00421 (0.02)				-0.0212 (0.07)
UsRank: 51-100				-0.0211 (0.02)				0.0129 (0.02)				-0.055 (0.08)
UsRank: >100				-0.0132 (0.02)				0.0306 (0.02)				-0.0569 (0.10)
Ln(Rd expenses in the university)				0.000368 (0.00)				-0.0102* (0.01)				0.0171 (0.02)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Biz. on pat	Biz. on pat	Biz. on pat	Biz. on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. not on pat	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.	Biz. on pat vs. not onpat.
TTO: Presence				0.0258				-0.00648				0.0358
				(0.03)				(0.04)				(0.16)
TTO: Post Bayh-Dole				0.00902				-0.0112				0.0538
				(0.01)				(0.01)				(0.04)
Public university				-0.0159				-0.00597				-0.0629
				(0.01)				(0.02)				(0.06)
University fixed effects	NO	NO	YES	NO	NO	NO	YES	NO	NO	NO	YES	NO
Constant	-0.00869	-0.0668*	-0.0477	-0.0921	-0.00557	-0.107**	-0.109**	-0.0412	0.341*	0.496**	0.488***	0.4
	(0.01)	(0.04)	(0.04)	(0.07)	(0.01)	(0.05)	(0.05)	(0.09)	(0.18)	(0.20)	(0.18)	(0.34)
Observations	10684	5924	5924	5432	10684	5924	5924	5432	1714	1049	1049	954
Adjusted R-squared	0.01	0.11	0.11	0.11	0.02	0.07	0.08	0.08	0.01	0.23	0.26	0.23
F test	36.01	30.57	28.06	13.48	50.20	21.63	21.05	11.00	5.98	41.42	23.11	19.74
prob>F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*** p<0.01, ** p<0.05, * p<0.1

Robust standard errors in parentheses

Linear probability OLS models, Inverse probability weights

B. Figures

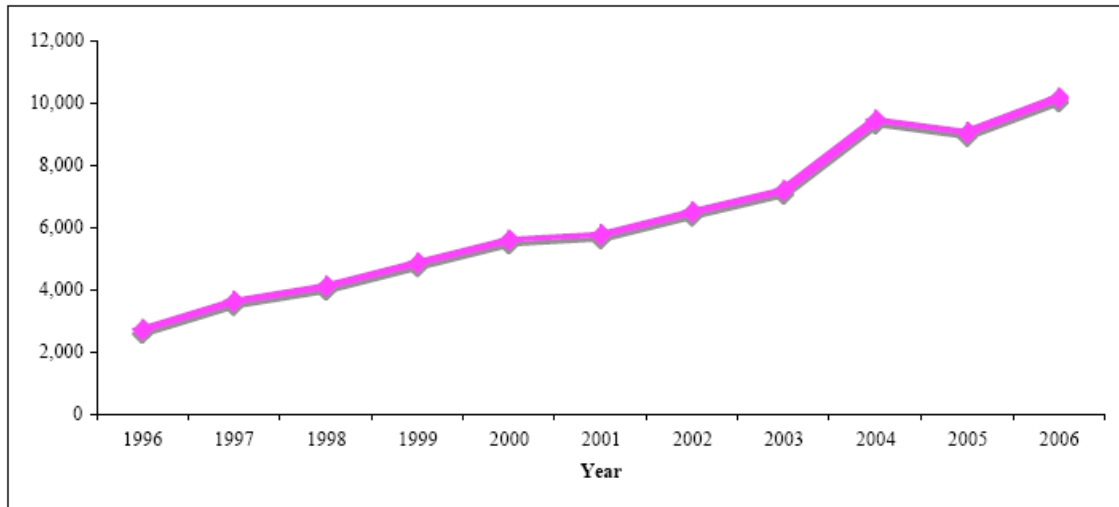


Figure 1: New US Patent applications filed by US universities (AUTM)

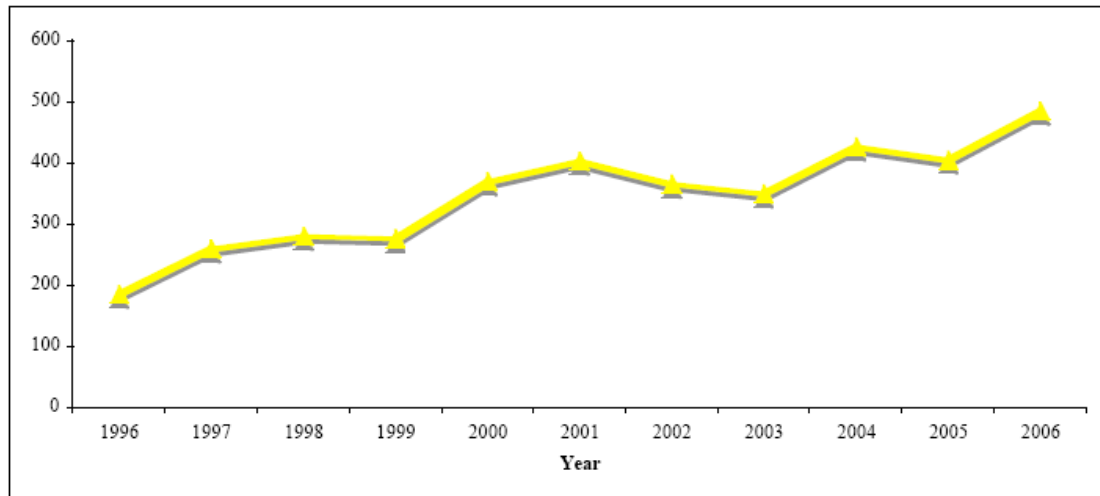


Figure 2: Academic start-up companies formed in the US (AUTM)

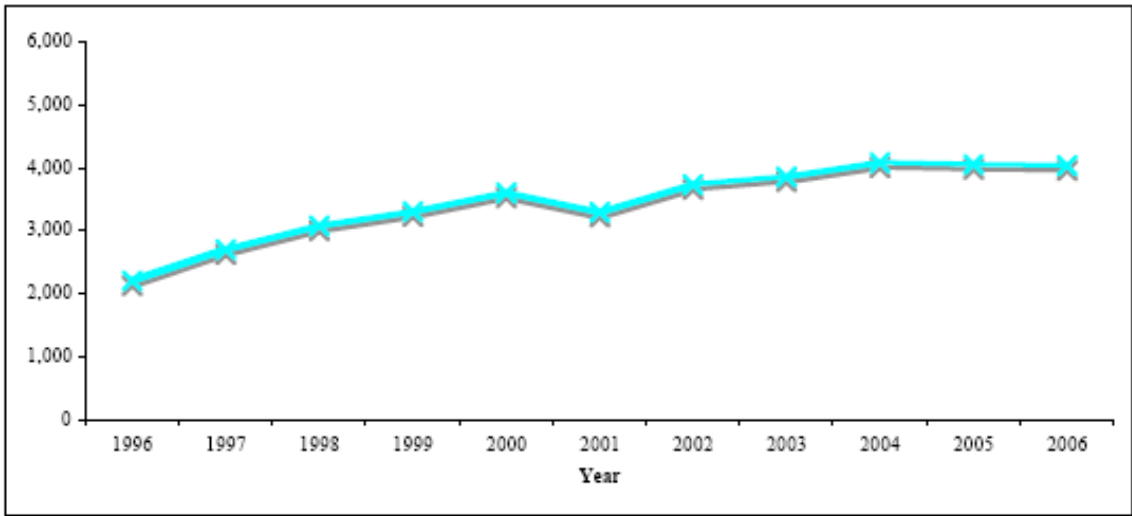


Figure 3: Licenses/Options executed in US universities (AUTM)

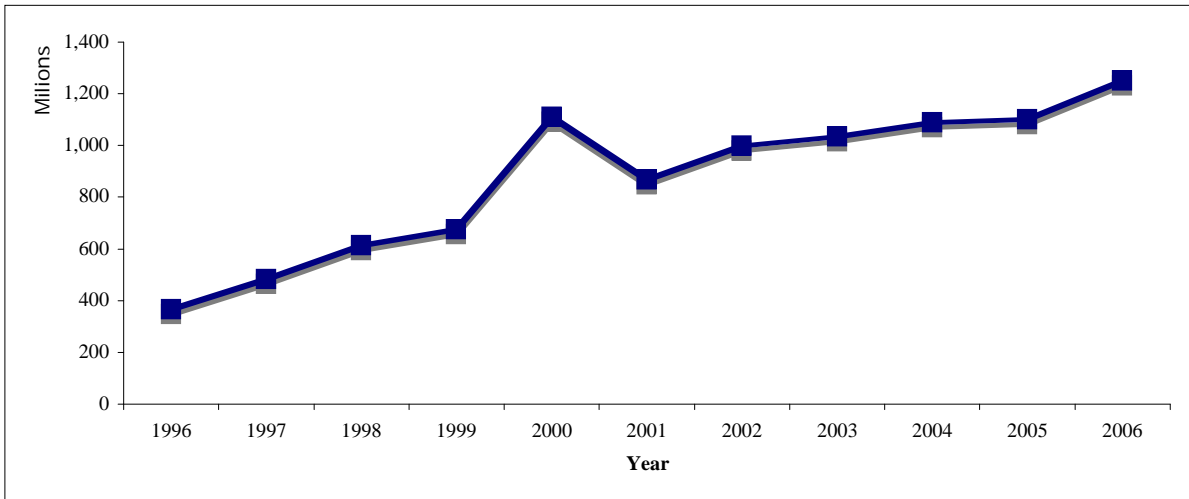


Figure 4: Gross license income received by US universities (AUTM)

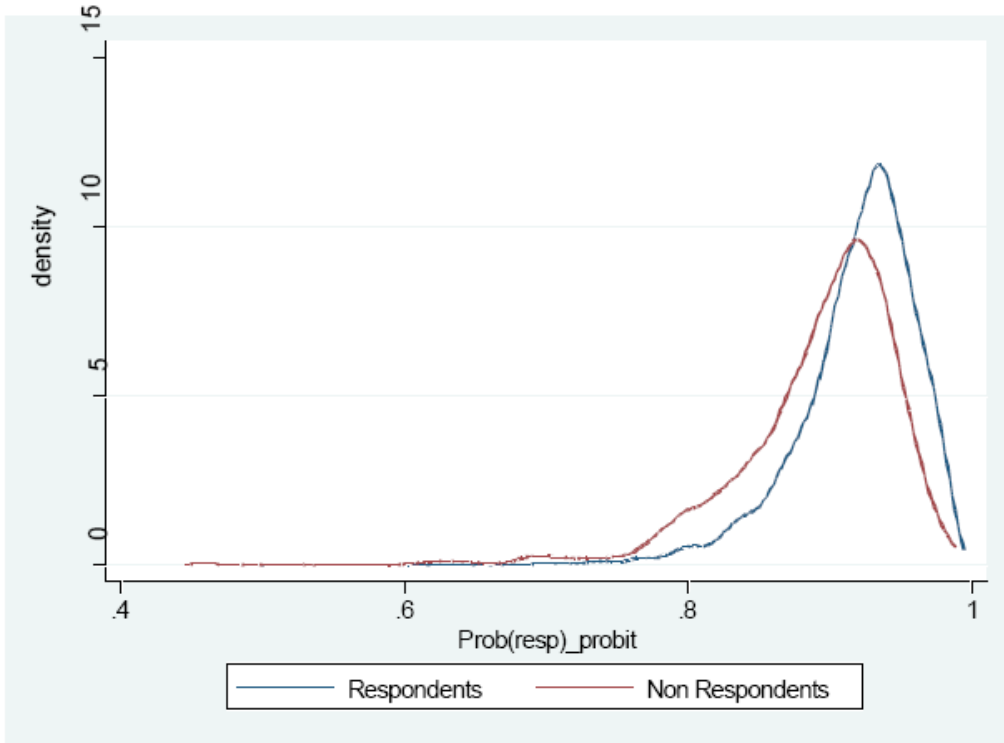


Figure 5: Distribution of predicted values for respondents and non respondents

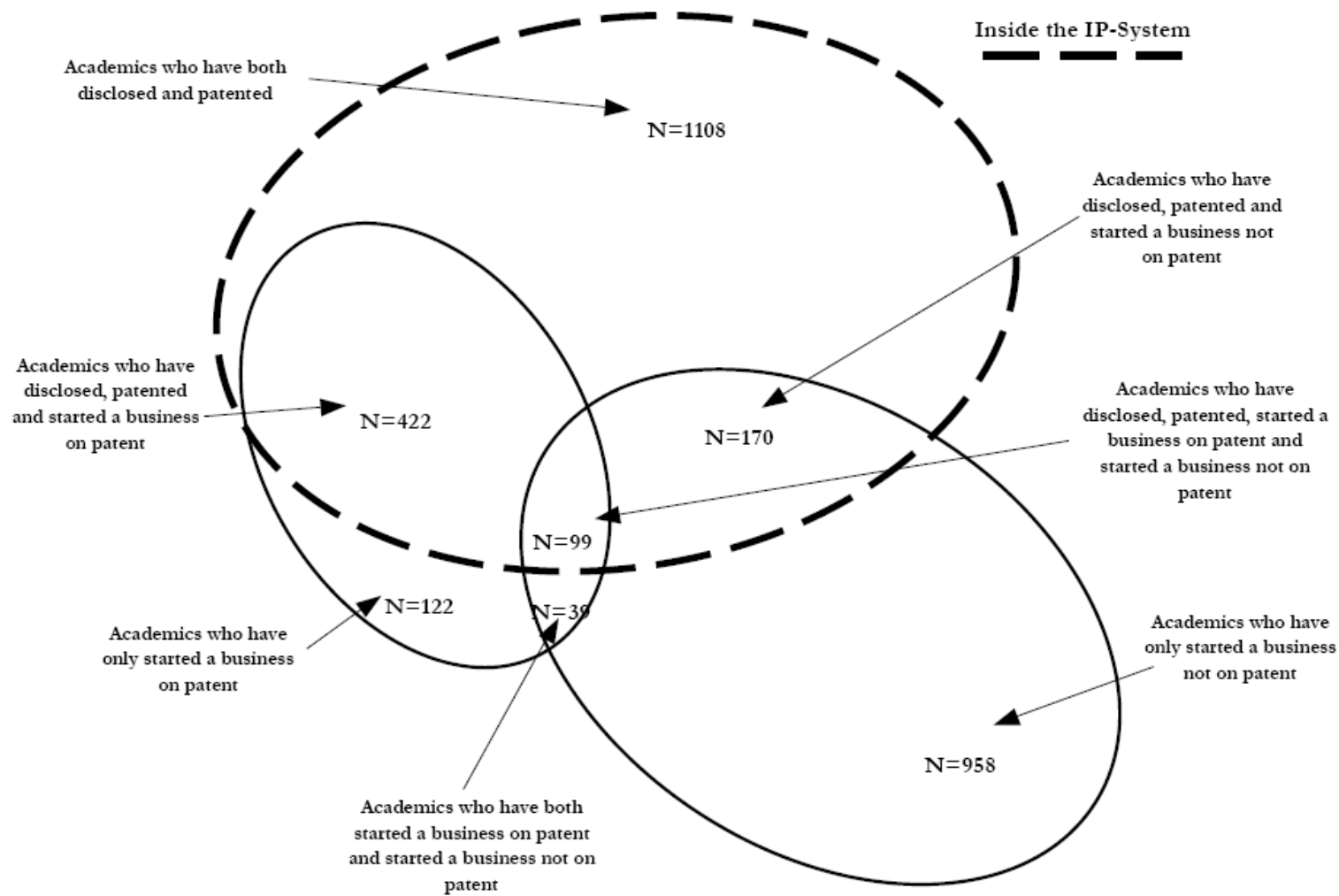


Figure 6: Commercial Activity Inside and Outside the IP-system

Note: We omitted licensing as it represents a complementary activity if compared to starting a business based on a patented invention.

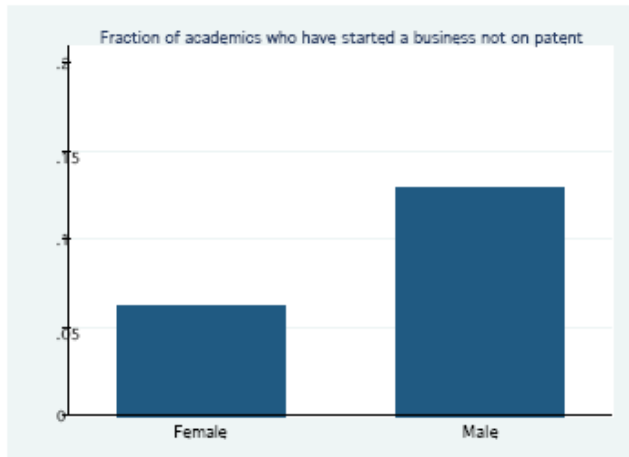
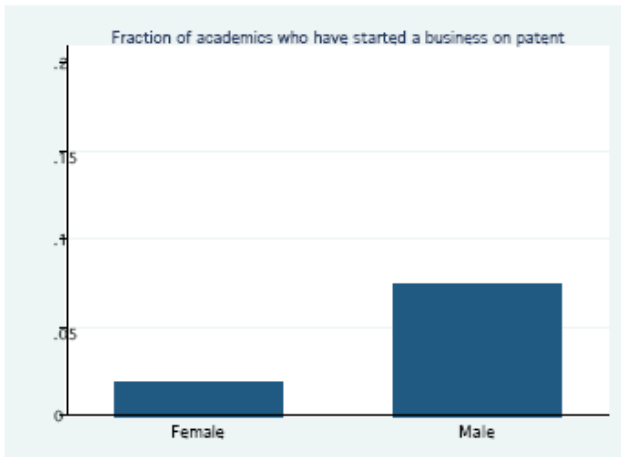


Figure 7: Business creation by gender

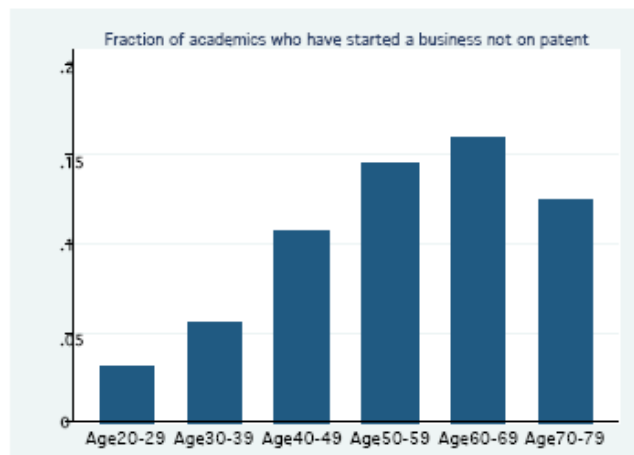
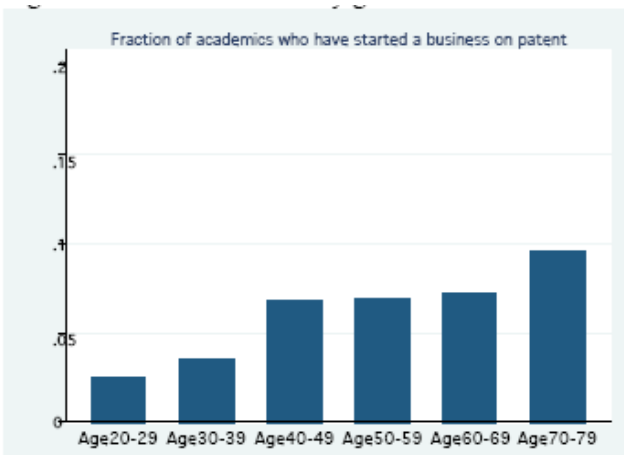


Figure 8: Business creation by age

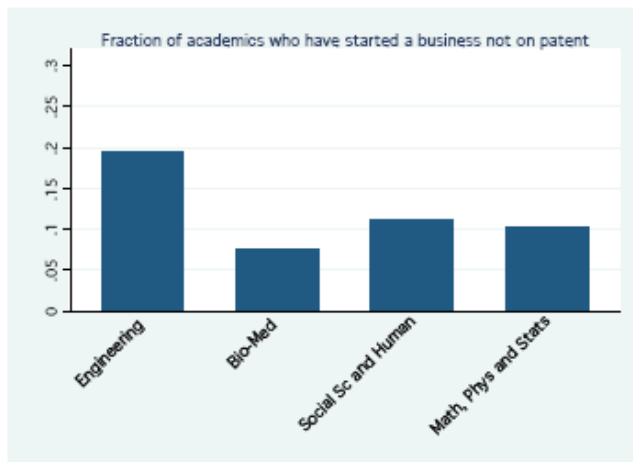
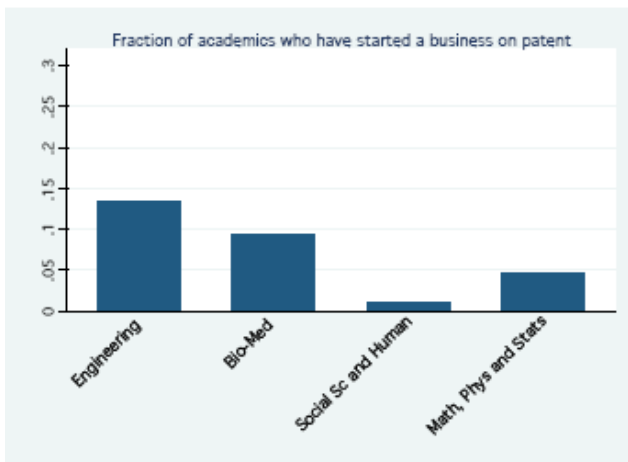


Figure 9: Business creation by disciplinary area

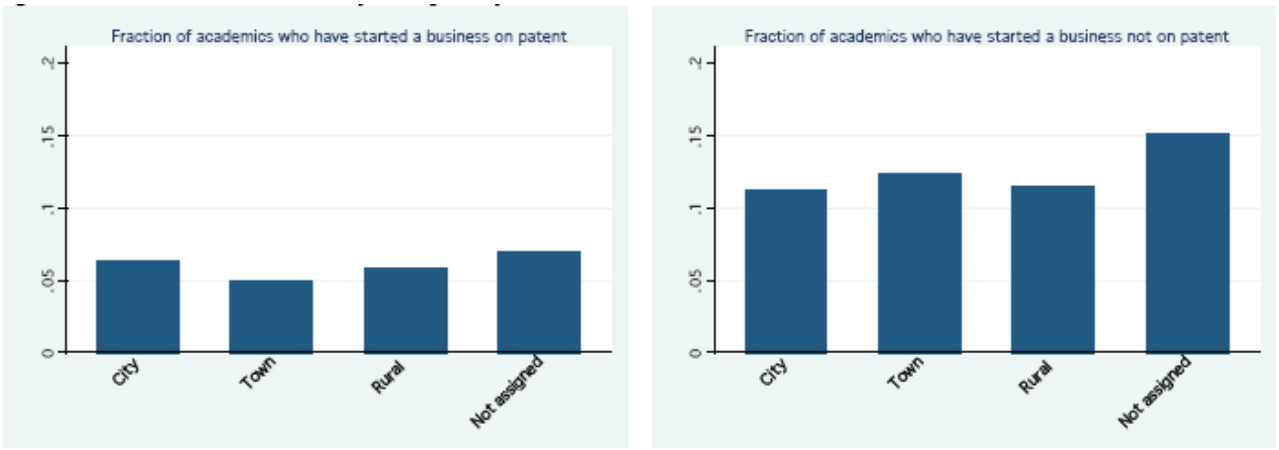


Figure 10: Business creation by school location

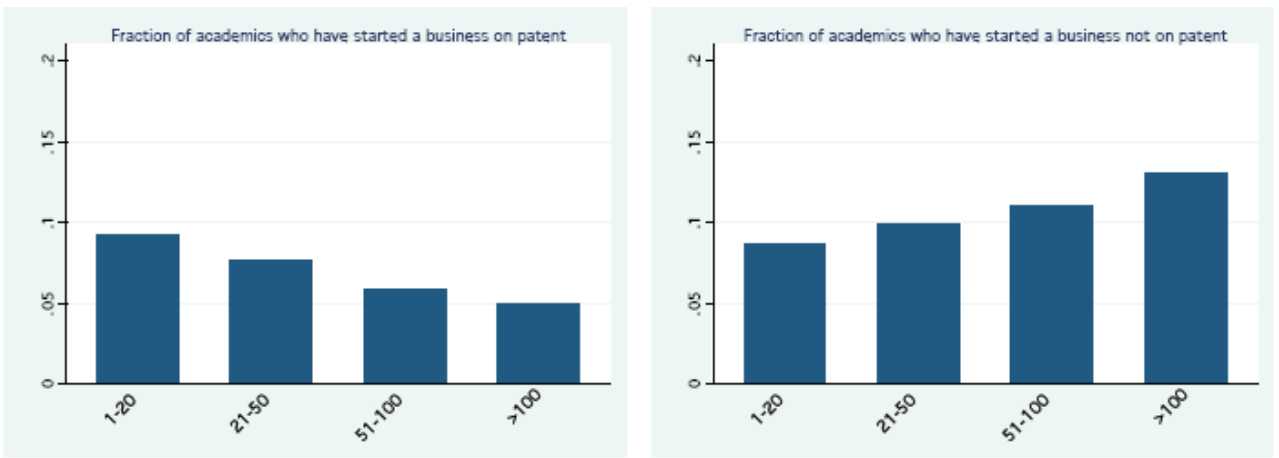


Figure 11: Business creation by school US News and World Report rank

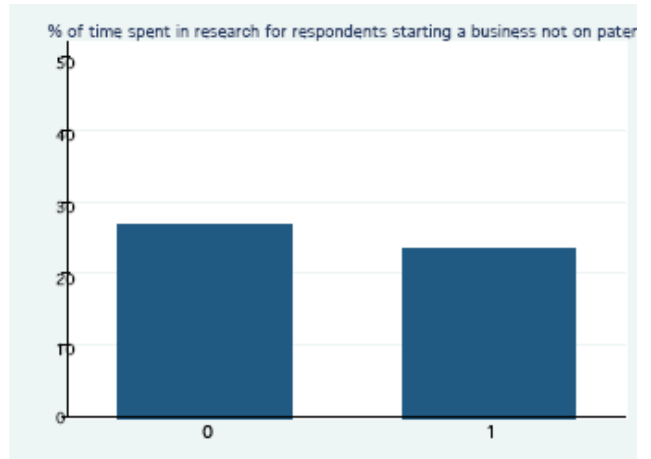
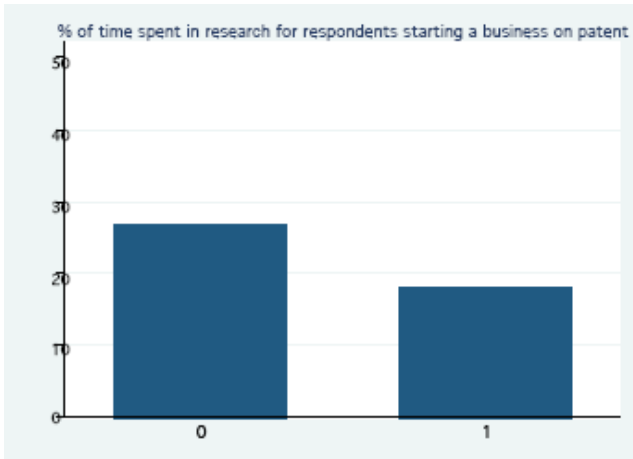


Figure 12: Time allocation -- research

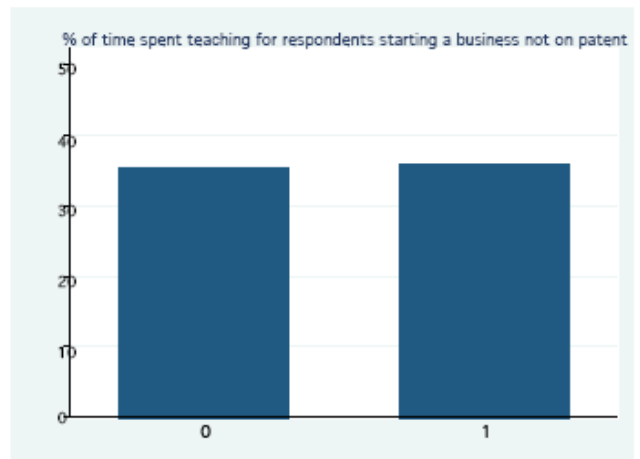
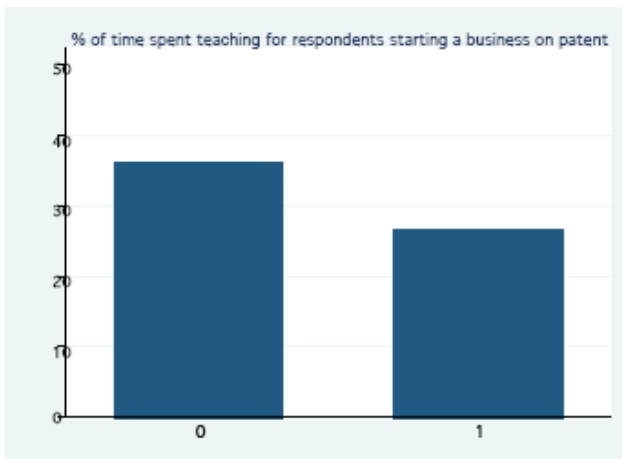


Figure 13: Time allocation -- teaching