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Inside or outside the IP system? Business creation in academia☆

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ABSTRACT

Research and public policy on academic entrepreneurship are largely based on the assumption that faculty members start businesses to commercialize inventions that have been disclosed to university administrators and have been patented. In this paper, we analyze a sample of 11,572 professors and find that much academic entrepreneurship occurs outside the university intellectual property system. Specifically, about 2/3 of businesses started by academics are not based on disclosed and patented inventions. Moreover, we show that individual characteristics, departmental and organizational affiliations, and time allocation of academics that have started business outside the IP system are different from those of academics that have started businesses to exploit disclosed and patented inventions. We discuss the implications for research on and the practice of academic entrepreneurship.

1. Introduction

Discussion of academic entrepreneurship often focuses on faculty efforts to commercialize inventions that they have disclosed within the intellectual property (IP) system established by university administrators. Some evidence, however, suggests that a sizeable amount of academic entrepreneurship occurs outside of this system (Bekkers and Bodas Freitas, 2008; Link et al., 2007; Martinelli et al., 2008). This 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, by extension, differences in the characteristics of the individuals involved with those activities) may have important consequences if unacknowledged by researchers and policymakers. First, researchers might systematically underestimate the depth and breadth of academic entrepreneurship. Second, various types of university researchers from a range of technical fields and institutions may be more likely to engage in entrepreneurial activities outside the formal system than in entrepreneurial activity through formal IP channels. As a result, efforts aimed at stimulating only formal IP-based entrepreneurial activities might fail to influence entire categories of individuals and entire academic disciplines, thereby hampering efforts to generate more entrepreneurial activity from universities.

This paper is based on a survey of 11,572 university professors, representative of the population of 58,646 academics who are affiliated with Carnegie I and II United States universities and employed in National Research Council-tracked disciplines. We find that a large share of academic entrepreneurship occurs outside the IP system and that the academics who undertake this activity differ from those who engage in academic entrepreneurship within the formal IP system. In particular, our findings reveal that approximately two-thirds of businesses started by academics are not based on disclosed and patented inventions. Moreover, we show that researchers whose entrepreneurial activities are based on inventions disclosed to universities are younger than those whose entrepreneurial outputs are not based on disclosed inventions. We also show that researchers who undertake entrepreneurial activities inside the IP system spend less time on research and teaching, and more time interacting with industry, as compared with those who operate outside the system. Finally, academics in the biosciences are more likely than other academics to be involved in entrepreneurial activities that are based on disclosed and patented inventions, whereas academics in social sciences and engineering are more likely to be involved in entrepreneurial activities that are not based on such inventions.

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These findings have implications for the development and testing of theories of academic entrepreneurship, as well as for the practice of knowledge transfer from academia to the business world. First, 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 academics' motivations for engaging in entrepreneurial activity, the types of academic efforts that faculty seek to commercialize, and the characteristics of those who engage in this activity. Second, if university administrators, business leaders and government officials believe that academic entrepreneurship is a valuable activity and intend to encourage it, then they need to have accurate estimates of its frequency, clearer parameters of who exactly is engaging in it, and an understanding of why they do so. Absent or inaccurate information can lead to efforts that do not encourage adequate 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.

2. Knowledge transfer and academic entrepreneurship inside and outside the IP system

Over the past 30 years, interest in the commercialization of knowledge developed within universities has increased.[1] Commercialization of university research has come to be considered a natural stage in the evolution of the modern university, which adds economic development 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 (Etzkowitz, 2004; Gibbons et al., 1994; Zucker and Darby, 1995).

Efforts to commercialize academic research manifest themselves in many different forms, such as patenting, licensing of inventions, and new business creation. Government officials and university administrators have increasingly put effort into stimulating and supporting these activities. In the United States, for example, legislation to stimulate universities to undertake more industrially relevant research, including the 1980 Bayh-Dole Act and the 1986 Federal Technology Transfer Act, have been put into place. Similar initiatives have been undertaken more recently in Europe and Japan (Geuna et al., 2003).

During the last decade, efforts to commercialize university-assigned inventions have increased dramatically. In the United States, the number of new U.S. patent applications by academic institutions has risen from fewer than 3000 in 1996 to more than 10,000 in 2006. The number of licenses and options executed by academic institutions has increased from slightly more than 2000 in 1996 to slightly more than 4000 in 2006, and gross license income received by academic institutions has increased from less than $400 million in 1996 to more than $1.2 billion in 2006. Finally, the number of start-up companies formed to commercialize university research has grown from fewer than 200 in 1996 to almost 500 in 2006 (AUTM, 2006).

However, all of the commercial activities reported in the official statistics are those that occur within the formal IP system. In fact, the process of knowledge transfer and academic entrepreneurship is often envisaged as a process that starts with an invention disclosed to a technology transfer office, 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 (Mowery et al., 2002). Scholars have examined all aspects of this process, including invention disclosures (Friedman and Silberman, 2003; Thursby and Thursby, 2005), patenting (Bercovitz and Feldman, 2008; Coupe, 2003; Hall et al., 2001; Henderson et al., 1998; Mowery et al., 2002; Mowery and Ziedonis, 2002; Sampat et al., 2003), licensing (Jensen and Thursby, 2001; Jensen et al., 2003), and the creation of new businesses to exploit university-assigned intellectual property (Markman et al., 2004; Mustar et al., 2006; Nerkar and Shane, 2003).

This focus on university-assigned IP is understandable, given the paucity of data on commercial activity outside of the formal IP system. This focus is particularly prevalent when the subject under investigation is new business creation, given the general lack of data on this topic. However, it does raise several questions worth considering. 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 commercial activity by academics, such as consulting and collaboration with industry, occur outside the formal IP system (Balconi and Laboranti, 2006; Beath et al., 2003; Cohen et al., 1998; Dechenaux et al., 2007; Jensen and Thursby, 2001; Jensen et al., 2007; Mansfield, 1995, Martinelli et al., 2008; Niosi, 2006).[2]

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 part of the process, because different industries make very different use of formal intellectual property rights, and because the value of patents differs across industries (Cohen et al., 2000; Klevorick et al., 1987). Scholars in the biological and chemical sciences, in which patents tend to be more effective at protecting inventions, might be more likely to engage in academic entrepreneurship through the formal IP system than scholars in engineering and the social sciences, in which patents are less important appropriability mechanisms (Martinelli et al., 2008).

Third, do different types of academics engage in academic entrepreneurship inside and outside the formal IP system? To some extent, this choice is an individual one that might be influenced by personal characteristics, such as age, experience, and tenure in academia. More senior academics, for example, might have developed more of a reputation and, therefore, be more 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

[1] Within this vast literature, see, among others: Azoulay et al. (forthcoming); Balconi and Laboranti (2006); Baldini (2009); Baldini et al. (2007); Carayol (2007); Clarysse et al. (2005); Dahlstrand (1997); Di Gregorio and Shane (2003); Fabrizio and DiMinin (2008); Martinelli et al. (2008); Mustar (1997); Mustar et al. (2006); Niosi (2006); O'Shea et al. (2008); Powers and McDougall (2005); Thursby et al. (2009); Zhang (2009). Rothaermel et al. (2007) provided an extensive literature review.

[2] Somewhat in contrast with the empirical literature that tends to be focused on very specific types of commercial activities by academics, the theoretical literature explains entrepreneurial activities by academics in ways not predicated on university intellectual property rights (Aghion et al., 2008; Lacetera, 2009; Thursby et al., 2007).

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 Pharmacology
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

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 lecturers 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. A full list of departments is reported in Table 1.

The survey was administered electronically and sent to email addresses that were obtained from university websites during the first half of 2007.[3] 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 for which participation is voluntary (Bekkers and Bodas Freitas, 2008; Lee et al., 2001).

3.2. The questionnaire

The questionnaire encompassed four main sections. In the first section, we gathered demographic 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 about the respondents' 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 2006–2007 academic year. The third section collected information about the commercialization of a respondent's academic research. Respondents were asked, in particular, whether they had disclosed inventions, whether they held U.S. patents (as inventors), and how many businesses they had started based on their research. The fourth section of the questionnaire asked questions only of those academics that had started companies. We gathered information, in particular, about the year of establishment of the business, its current status, and the financial returns to the academic entrepreneur from having started the business.

The present study focuses on business creation by faculty members. In particular, we will exploit the question in which the respondents were asked to indicate how many of the businesses they had started were based on a patent or IP-protected knowledge. The answer to this question allows us to distinguish academics that have started businesses based on patents, and those who have started businesses not based on a patent, thus making it possible to address some of the unanswered questions in the literature.

3.3. Additional data sources

In addition to the information collected through our survey, we gathered secondary information on the respondents' universities. Information was obtained from three main sources: The Carnegie Classifications Data File 2008; the Association of University Technology Managers (AUTM) U.S. Licensing Activity Survey: FY2006; and *U.S. News and World Report*: America's Best Colleges. The collected data include information about university ownership (public/private); number of faculty; R&D expenditures; location; technology transfer support mechanisms and technology transfer outputs (e.g., existence of a TTO, starting year of technology transfer program, number of university spin-off companies formed, new U.S. patent applications filed and licenses/options executed); as well as the university's quality rank as defined by *U.S. News and World Report*.

3.4. Overall data description

Of the 11,572 respondents, about 78 percent of the respondents were male. The average and median age was approximately 49 years old. About 70 percent of the respondents held tenured positions, with at least 10 years of experience in academia at the time of participation in the survey. The average respondent had published 53 articles at the time of the survey and had raised about $285,000 of research funds in the 2006–2007 academic year.

On average, respondents reported that about 6.5 percent of their research funds came from for-profit companies. This reported share is very close to the National Science Foundation's estimate of industry funding of academic research (NSF, 2005).

As for the time allocation of the academics during 2006–2007, interactions with industry people averaged 2.4 percent of the respondents' non-administrative time, while teaching and research occupied, respectively, 35.3 percent and 26.2 percent of that time. Writing grants, managing PhD students, and attending conferences accounted for the remaining 35 percent of the time.

[3] 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).

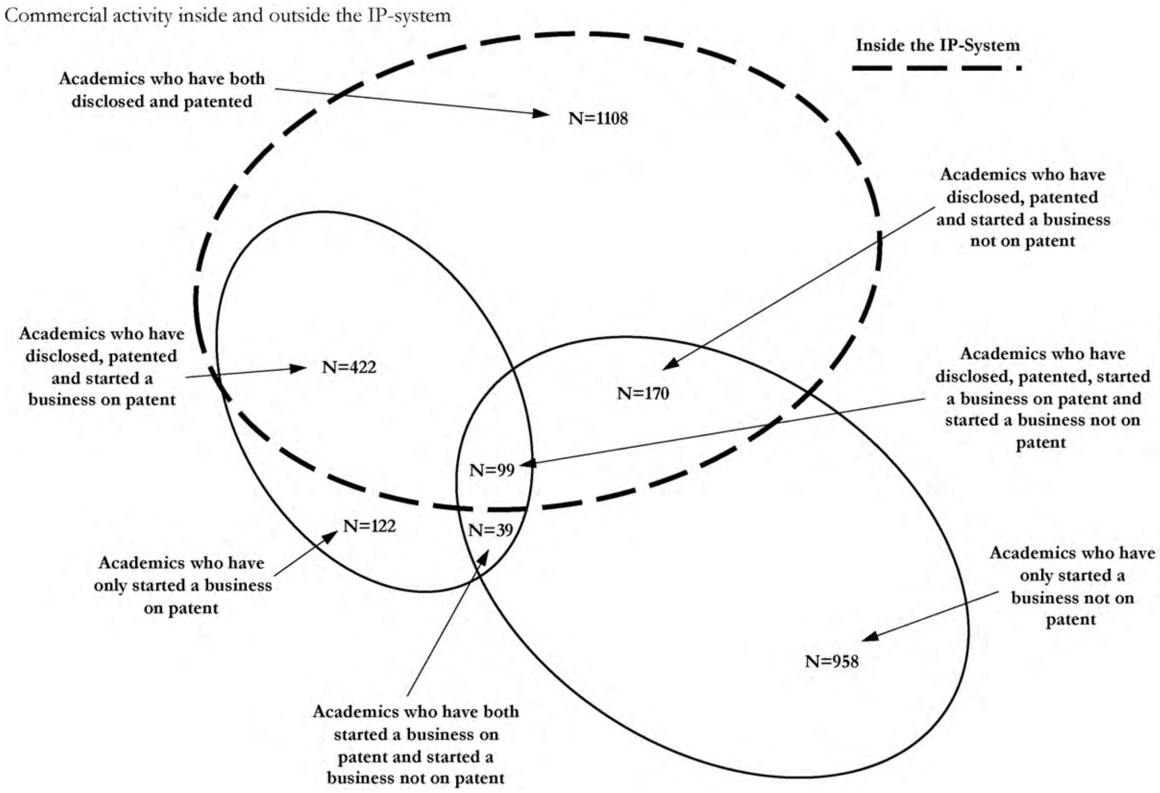

Fig. 1. Commercial activity inside and outside the IP system. Note: We omitted licensing as it represents a complementary activity if compared to starting a business based on a patented invention.

About 21 percent of respondents were in Engineering disciplines, 20 percent in Biological and Medical Sciences, 33 percent in Social and Human Sciences, and 26 percent in Mathematics, Physics, and Statistics. More that 70 percent of respondents were employed by public universities, and 12 percent were employed by the top 20 universities (according to the *U.S. News* ranking). Approximately 97 percent of the respondents worked at a university where a Technology Transfer Office (TTO) is present, and, in 77 percent of the cases, the TTO was established after the passage of the Bayh-Dole Act.

As reported in Table 2, the most frequent commercial activities engaged in by the respondents were patenting and licensing (which, in turn, imply disclosure) of inventions, followed by company creation. However, most of the academics surveyed did not engage in commercial activities; only about 36 percent of the sample had undertaken any of these activities during their academic careers.

3.5. The "outside the system" academic entrepreneurs

Table 3 (panels a, b and c) describes the respondents who started businesses. Fig. 1 provides a graphical representation of the subset of respondents who started at least one business on patents and not on patent, as they relate to other types of commercialization activities reported in the questionnaire.

Fig. 1 and Table 3 suggest that the use of invention disclosures to define the sampling frame for academic entrepreneurship is problematic. The majority of respondents who started new firms did not do so to exploit a patented invention. Overall, 1266 respondents (about 11 percent of the overall 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, as Fig. 1 shows, the population of academics starting businesses that are not a result of a patented invention does not overlap with academics operating inside the IP system. The figure shows that 958 academics that have established a company which is not based on a formal piece of intellectual property also have not performed any of the other commercial activities. In contrast, only 170 academics have started a business that is not based on patent and also have disclosed an invention and filed at least one patent, and only 99 academics have both started a business not on a patent and undertaken the entire set of IP-based entrepreneurial activities (i.e. disclosed an invention, filed at least one patent, and started a business based on patent). [4] Business creation inside and outside the formal IP system appear to be following markedly different processes.

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 previous discussions of the topic. While important, this fact is not sufficient to argue that different approaches are necessary in order to understand and support this activity. For that, we need evidence of systematic differences between the academic entrepreneurship that takes place inside and outside the formal IP system.

Table 3 suggests the differences between these two classes of academic entrepreneurs. The prevalence of male entrepreneurs is more marked for those who started a business based on a patent. Furthermore, those who have started companies based on IP are younger than those starting ventures not on IP. A striking

[4] There are also 138 respondents who have started businesses both on a patent and not on a patent. In the analyses below we include these and classify them as having started a business on a patent, in order to classify the "non-IP based" entrepreneurs in more strict terms. The analyses however are robust to excluding these 138 respondents.

Table 2
Entrepreneurial activities.

Commercial activities	*N*	Mean	Std. dev.	Min	Max	Median	Skewness	Kurtosis
Number of disclosures	11,311	1.42	6.08	0	350	0	23.17	1057.11
Number of Us patents issued	11,302	0.95	4.40	0	131	0	11.92	215.14
Number of licenses	11,200	0.35	2.23	0	70	0	15.59	341.54
Number of new business started	10,825	0.25	0.90	0	52	0	22.40	1096.96
Number of new business started on patent	11,157	0.09	0.41	0	10	0	7.69	96.06

Table 3a
Descriptive statistics.

	Percentage of respondents having started a business		
	Overall	On patent	Not on patent
Gender	(*N* = *1714*)	(*N* = *638*)	(*N* = *1076*)
Female	10.85	6.58	13.38
Male	89.15	93.42	86.62
Total	100.00	100.00	100.00
Age	(*N* = *1691*)	(*N* = *630*)	(*N* = *1061*)
20–29	0.47	0.63	0.38
30–39	12.00	13.49	11.12
40–49	27.68	30.95	25.73
50–59	35.19	31.43	37.42
60–69	21.58	19.37	22.90
70–79	3.08	4.13	2.45
Total	100.00	100.00	100.00
Academic rank	(*N* = *1714*)	(*N* = *638*)	(*N* = *1076*)
Professor with Endowed Chair	14.24	19.59	11.06
Full Professor	47.37	48.59	46.66
Associate Professor with Tenure	21.12	18.50	22.68
Associate Professor without Tenure	3.50	2.82	3.90
Assistant Professor	10.33	8.93	11.15
Lecturer	3.44	1.57	4.55
Total	100.00	100.00	100.00
Years in Academia	(*N* = *1709*)	(*N* = *636*)	(*N* = *1073*)
From 0 to 5	*131*	7.08	7.55
From 6 to 10	12.58	12.58	12.58
From 11 to 15	13.40	13.84	13.14
From 16 to 20	16.79	17.77	16.22
From 21 to 25	13.93	14.62	13.51
More than 26	35.93	34.11	37.00
Total	100.00	100.00	100.00
Disciplinary areas	(*N* = *1714*)	(*N* = *638*)	(*N* = *1076*)
Engineering	37.51	50.15	30.02
Biomedical Sciences	15.06	17.87	13.38
Social Sciences	24.97	4.86	36.90
Physics and Mathematics	22.46	27.12	19.70
Total	100.00	100.00	100.00

difference emerges also in the distribution of IP-based and non-IP-based academic entrepreneurs across disciplines. Academics that have started a business based on a patent are predominant in the biology/chemical area, while those who have started a business not based on a patent are overrepresented in the social sciences. Respondents who have started a business on a patent are relatively more clustered in engineering and mathematics/physics disciplines than respondents who have started a business not on a patent, but, in absolute numbers, there are more respondents who have started businesses not on patent in these disciplinary areas.

Finally, academics who started a business on a patent allocate a smaller amount of their time to teaching and research (not including activities like writing grants and managing students) than those who started a business not on a patent, and a considerably higher share of their time interacting with industry than respondents who started a business not on a patent. Patent-based entrepreneurs, on the other hand, appear to have published more and to have received a higher amount of research funds in the 2006–2007 academic year than non-patent-based entrepreneurs. We now turn to assess the robustness of these differences to regression analysis.

Table 3b
Descriptive statistics (con't): research output.

Respondents having started a business									
Research activities	Overall			On patent			Not on patent		
	N	Mean	Median	*N*	Mean	Median	*N*	Mean	Median
Number of academic articles published	1708	73.5	50	637	105.6	80	1071	54.4	35
Total value of research funding (2006–2007)	1659	524,704	150,000	626	747,840	300,000	1033	389,484	75,000

Table 3c
Descriptive statistics (con't): time allocation and sources of funding.

	Percentage of respondents having started a business		
	Overall	On patent	Not on patent
Source of research funding (% of 2006–2007 research funds)	(*N* = *1347*)	(*N* = *569*)	(*N* = *778*)
Profit company	14.31	19.06	10.83
Goverment agency or other public source	63.13	66.40	60.74
Foundation or other non-profit organization	9.21	6.91	10.90
Your institution	13.35	7.63	17.54
Total	100.00	100.00	100.00
Time allocation of academic work (% of 2006–2007 time)	(*N* = 1305)	(*N* = *508*)	(*N* = *797*)
Teaching	32.68	26.59	36.56
Researching	21.81	17.81	24.35
Meeting industry people	5.34	6.01	4.92
Writing grants	13.08	16.91	10.64
Managing PhD students	20.99	26.28	17.61
At conferences	6.10	6.40	5.92
Total	100.00	100.00	100.00

4. Regression analysis

4.1. Regression models

The distribution of commercial activities in general, and of the number of business started in particular, is highly skewed, with a few outliers who are heavily engaged in these activities (we report medians in Table 2 in order to better document this point). Because of this high skewness (and because of possible report and recall errors and biases), we rely on dichotomous variables in the following analyses, considering whether the respondents have started a business based on a patent, and whether they have started a business not based on a patent. Our focus on dichotomous measures of business creation is also consistent with the main goal of this paper, which is the exploration of the differences between academics starting businesses based or not based on intellectual property. Table 4 reports the variables used in the regressions.

First, we wanted to ensure that the businesses created by entrepreneurs operating within and outside the IP system were not substantially different in their viability and potential to create value. To test whether there were significant differences between the two types of academic entrepreneurship on these dimensions, we looked at the year that the business was founded; the income made by the respondent from the firm (expressed as a percentage of the 2006–2007 academic salary); whether the firm was still in operation; and whether the company was public at the time of the survey. We found no discernible difference between businesses started on patents and not based on a patent in terms of financial return to the respondents, nor is there any difference in the share of these companies that have gone public.[5] A significant difference emerges, however, in the share of companies that were still in operation at the time of the survey and the founding years of the businesses, because businesses started on a patent are more likely to be still in operation. For this reason, in the main regression models we include a dummy variable for whether the business was still in operation at the time of the survey, and a continuous variable measuring the year of business founding.

We were also concerned that the 20 percent of the sample that responded to the survey (regardless of whether they started a business or not) might not be representative of the overall population.[6] In order to address this issue, we drew a random sample of 1000 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 1000 non-respondents will inform us about the representativeness of our sample. In order to assess the presence of selection, 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.

Table 5 reports the results of our probit regressions to examine the issue of selection. Given the high number of observations, it is not surprising that some coefficient estimates are precise and, therefore, significantly different from zero in statistical terms. The size of the significant coefficients, however, is very small in most cases, suggesting, again, that sample selection is not a major issue in our research. Nevertheless, to ensure that response bias does not affect our data, in the following analysis, we provide our results both uncorrected and corrected for selectivity through inverse probability weighting in the main regressions to show convergent validity between efforts to control for these effects and examination of a more selected sample (Wooldridge, 2002).[7]

Table 6 reports the results from the regressing the probability of starting a business based on a patent – as opposed to starting a business not based on a patent – on a number of covariates. In column (1), we include only individual characteristics, such as gender and age. In column (2) we add 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 (as expressed by the log of value

[5] The fact that we do not find differences on these dimensions *at a given point in time* does not exclude the possibility that differences might emerge in the future. For example, if IP-based startups are more likely to be product-based, then it might take them longer, than, say, consulting startups to show their potential. We are grateful to a referee for suggesting this point.

[6] For example, faculty with greater experience in (or propensity to) commercializing their research might have a greater incentive to complete the survey. Alternatively, professors who are engaged in a high number of commercial activities 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.

[7] 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 5. Weights for each observation are given by the inverse of the predicted values of the same observation in the selection regression.

Table 4
Variables included in the regression models.

Variable	Type	Description
Biz on pat	Dummy	Variable = 1 if at least one business started on patent.
Biz not on pat	Dummy	Variable = 1 if at least one business started on patent not on patent.
Male	Dummy	Variable = 1 if respondent is male.
Age	Dummy (6 categories)	Categories: age: 20–29 (baseline); age: 30–39; age: 40–49; age: 50–59; age 60–69; age: 70–79
Ln(Number of academic articles)	Continuous	Ln(Number of academic articles).
Ln(Value research funds 2006–2007)	Continuous	Ln(Total value of research funding (2006–2007)).
Time: % in teaching (2006–2007)	Continuous	% of 2006–2007 time in teaching.
Time: % in researching (2006–2007)	Continuous	% of 2006–2007 time in researching.
Time: % in meeting industry (2006–2007)	Continuous	% of 2006–2007 time in meeting industry people.
Research funds: % from profit company (2006–2007)	Continuous	% of 2006–2007 research founding from profit company.
Dept	Dummy (4 categories)	Categories: Engineering (baseline); Biological and Medical Sciences; Social and Human Sciences; Mathematics, Physics and Statistics.
Year	Continuous	Year of foundation of most recent business by respondent
Still alive	Dummy	Variable = 1 if most recent business by respondent is still in operation

Table 5
Probit regression of the probability of being a respondent.

	Dep. Var.: 1 if respondent 0 if non respondent
Male	−0.0059
	(0.006)
Age: 30–39	−0.0196
	(−0.025)
Age: 40–49	−0.0290
	(0.025)
Age: 50–59	−0.0201
	(0.024)
Age: 60–69	−0.0491*
	(0.029)
Age: 70–79	−0.130***
	(0.048)
Dept: Bio-Science	0.0081
	(0.007)
Dept: Social and Human Behavior	0.0030
	(0.007)
Dept: Physics and Math	−0.0079
	(0.008)
University fixed effects	YES
Observations	12,009
Pseudo R-squared	0.04
Chi^2 on all parameters	253.86
Prob > chi^2	0.00
Chi^2 test on disciplinary areas dummy	5.26
Prob > chi^2	0.15
Chi^2 test on University dummies	190.13
Prob > chi^2	0.21

Standard errors in parentheses. Probit model, marginal effects reported.
* $p < 0.1$.
*** $p < 0.01$.

of research funds available in 2006–2007),[8] the allocation of their time across different activities, the sources of their funding, and dummy variables for their disciplinary areas. We also add university fixed effects to control for differences across schools.

Columns (3) and (4) provide the same regression models as in columns (1) and (2), but include the controls for the year of business founding and the dummy variable for whether the business is still active. Columns (5)–(8) of Table 6 replicate the analyses of columns (1)–(4) in regressions that include the selectivity correction. With this correction, 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 5).

All regressions are estimated through linear probability, OLS models. The regression table also reports Huber–White robust standard errors of the estimated parameters. [9]

4.2. 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 based on patents tend to be younger than those who started their businesses not based on patents. Second, the evidence indicates a trade-off between commercial activities on the one hand, and research and teaching on the other, for patent-based academic entrepreneurship, but not for non-patent-based academic entrepreneurship. Third, starting businesses based on patents is more likely to occur in the biosciences, while starting businesses not based on a patent are more likely to occur in departments related to social sciences and behavioral studies.[10] Fourth, the set of dummy variables for the different universities is jointly significant, but only marginally so.[11]

These results hold if we control for the year in which the latest business was started and whether the business is still in operation

[8] We use the natural logs of cumulative publications and funding in order to partially correct for the skewness of these variables, as can be seen in Table 3b.

[9] Probit and logit regressions convey very similar results. We report linear regressions results here because the estimates are more immediate to interpret in terms of marginal effects. The adjusted R-squared reported in the table are from the corresponding models with spherical standard errors (Stata does not report adjusted R-squared for model with robust standard errors).

[10] Because mathematical formulas cannot be patented, researchers in mathematics and statistics should be less likely to start businesses based on patents than researchers in computer science, physics and astronomy. Therefore, in additional analyses (available from the authors) we separated the aggregate technical field of physics, astronomy, statistics, mathematics, and computer science that we report in our main regressions and examined the effect of being in mathematics and statistics rather than other technical fields. We found that researchers in mathematics and statistics were significantly less likely than researchers in engineering (the omitted case) to start businesses based on patents.

[11] In further analyses not reported here (but available from the authors), we "unpack" the school fixed effects by substituting the school dummies with a series of time-invariant school characteristics that previous researchers have found to be associated with academic entrepreneurship: year of establishment, location, *U.S. 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 or after the Bayh-Dole act was passed (in 1980), and whether a university is public or not. We find that the only robust university-level variables that were statistically significant were those related to the geographic location of the institution.

Table 6
Regression results.

Variables	(1) Biz. on pat vs. not on pat.	(2) Biz. on pat vs. not on pat.	(3) Biz. on pat vs. not on pat.	(4) Biz. on pat vs. not on pat.	(5) Biz. on pat vs. not on pat.	(6) Biz. on pat vs. not on pat.	(7) Biz. on pat vs. not on pat.	(8) Biz. on pat vs. not on pat.
Male	0.155***	−0.0232	0.129***	−0.0317	0.156***	−0.0247	0.129***	−0.0334
	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)
Age: 30–39	−0.0564	−0.214**	−0.0269	−0.181*	−0.0518	−0.209*	−0.0231	−0.177*
	(0.18)	(0.11)	(0.18)	(0.09)	(0.18)	(0.11)	(0.18)	(0.09)
Age: 40–49	−0.0685	−0.260**	0.00435	−0.174*	−0.0654	−0.255**	0.00617	−0.170*
	(0.18)	(0.11)	(0.18)	(0.09)	(0.18)	(0.11)	(0.18)	(0.09)
Age: 50–59	−0.133	−0.310***	0.00682	−0.176*	−0.13	−0.308***	0.00861	−0.173*
	(0.18)	(0.11)	(0.18)	(0.10)	(0.18)	(0.11)	(0.18)	(0.10)
Age: 60–69	−0.152	−0.318***	0.0462	−0.132	−0.149	−0.315***	0.0478	−0.13
	(0.18)	(0.11)	(0.18)	(0.10)	(0.18)	(0.11)	(0.18)	(0.10)
Age: 70–79	0.0128	−0.112	0.261	0.0821	0.0236	−0.106	0.265	0.0818
	(0.19)	(0.15)	(0.19)	(0.13)	(0.19)	(0.14)	(0.19)	(0.13)
Ln(Number of academic articles)		0.0873***		0.0762***		0.0893***		0.0774***
		(0.02)		(0.02)		(0.02)		(0.02)
Ln(Total value of research funding (2006–2007))		0.0067		0.00308		0.00619		0.0026
		(0.01)		(0.01)		(0.01)		(0.01)
Time: % in teaching (2006–2007)		−0.00373***		−0.00314***		−0.00378***		−0.00323***
		(0.00)		(0.00)		(0.00)		(0.00)
Time: % in researching (2006–2007)		−0.00485***		−0.00384***		−0.00480***		−0.00380***
		(0.00)		(0.00)		(0.00)		(0.00)
Time: % in meeting industry people (2006–2007)		−0.00183		−0.0017		−0.00183		−0.00171
		(0.00)		(0.00)		(0.00)		(0.00)
Research founds: % from profit company		0.00230***		0.00212***		0.00229***		0.00212***
		(0.00)		(0.00)		(0.00)		(0.00)
Dept: Bio-Science		0.152***		0.110***		0.152***		0.108***
		(0.04)		(0.04)		(0.04)		(0.04)
Dept: Social and Human behavior		−0.167***		−0.165***		−0.164***		−0.163***
		(0.05)		(0.05)		(0.05)		(0.05)
Dept: Physics and Math		−0.0529		−0.05		−0.0537		−0.0524
		(0.05)		(0.05)		(0.05)		(0.05)
Year			0.0176***	0.0161***			0.0175***	0.0163***
			(0.00)	(0.00)			(0.00)	(0.00)
Stillalive			0.0435	0.0211			0.0438	0.0207
			(0.03)	(0.04)			(0.03)	(0.04)
Constant	0.345*	0.493***	−34.87***	−31.73***	0.341*	0.488***	−34.80***	−32.08***
	(0.18)	(0.18)	(2.53)	(3.85)	(0.18)	(0.18)	(2.53)	(3.85)
University fixed effects	NO	YES	NO	YES	NO	YES	NO	YES
Inverse probability weighting correction	NO	NO	NO	NO	YES	YES	YES	YES
Observations	1714	1049	1672	1025	1714	1049	1672	1025
Adjusted R-squared	0.01	0.26	0.11	0.31	0.01	0.26	0.11	0.31

Robust standard errors in parentheses. Linear probability OLS models.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

or not. The inclusion of these two variables does not change the estimate of the parameters associated to the other regressors in a substantive way.

5. Discussion and conclusion

The evidence provided 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 findings of this study: (1) a sizeable portion of academic entrepreneurs engage in commercial activity that lies outside the formal university IP system and (2) the characteristics of the academics that start non-patent-based companies are not well represented by their colleagues who start businesses based on their patents. These observations suggest that prior estimates of academic entrepreneurship based on activities that occur within the formal IP system understate the frequency of this activity and mischaracterize who tends to engage in it.

These findings have implications for our efforts to understand academic entrepreneurship. Because scholarly efforts, to date, have focused predominantly 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.

A few researchers have began to consider how entrepreneurial activities outside of the patent system occur. Balconi and Laboranti (2006), for example, discuss the importance of face-to-face interactions between academics and industry, regardless of the presence of formal IP. Martinelli et al. (2008) have noted that consultancy by academics tends to occur without any form of patent protection. Similarly, in their review of the literature of academic spin-offs, Mustar et al. (2006) distinguish between spin-offs that are service oriented and those that are product oriented. However, to date we do not yet have a complete understanding of academic entrepreneurship in all of its forms.

Second, we need studies of the broader range of academic entrepreneurship to generalize to the phenomenon. The differences between entrepreneurs who exploit university-assigned patents and those who do not might allow for only limited generalizability of the large body of literature on academic entrepreneurship that has been developed over the past 30 years. For example, previous studies have investigated the presence of trade-offs between traditional academic activities and commercial activities (Agrawal and Henderson, 2002; Azoulay et al., forthcoming; Breschi et al., 2007; Goldfarb et al., 2006). Our results suggest that these trade-offs (at least in terms of time allocation) might be limited to academic efforts to start companies based on the researchers' patents.

Our findings also have implications for the practice of academic entrepreneurship. Efforts to reinforce the intellectual property rights of universities 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, appear to be 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 Technology Transfer Offices, as is currently the practice, are failing to help a sizeable portion of academic entrepreneurs, whose entrepreneurial activities occur outside of the formal IP system in which TTOs exist. 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 those fields are where "the action lies." This creates problems for administrators concerned with university contributions to economic development or resource acquisition. By focusing on patent-based entrepreneurial activity, university administrators are ignoring the full potential for entrepreneurial activity present among their faculties.

Finally, our contribution has managerial implications as well. Several observers have argued that, in order to take full advantage of the potential for university technology transfer, firms should develop both formal and informal mechanisms for interacting with university researchers (Balconi and Laboranti, 2006; Grimpe and Hussinger, 2008). Our results support this argument; we show that a relevant facet of academic entrepreneurship occurs outside the 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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