

Who Are the Academic Entrepreneurs in the United States, and What Do They Do?*

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PRELIMINARY AND INCOMPLETE

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. If faculty efforts to commercialize their research; hold equity in businesses based on their academic activities; start companies; and license technologies that emerged from their academic activities is different for potentially patented inventions disclosed to university administrators than it is for the totality of these efforts, then research and public policy on academic entrepreneurship based on the analysis of samples of potential inventions disclosed to university administrators is potentially biased. This study tests the representativeness of efforts to predict the following aspects of academic entrepreneurship: (1) commercialize research (disclosing, patenting), (2) start companies, and (3) hold equity in companies based on one's research. Based on responses of 11,584 university professors to a survey of faculty in National Research Council ranked departments in Carnegie I and II universities, we find that these aspects of academic entrepreneurship are systematically different for efforts based on inventions disclosed to university administrators than they are for all academic entrepreneurship effort. The demographic characteristics of the faculty entrepreneurs, the academic activities of those entrepreneurs, and their academic fields all differ. These findings have implications for efforts to develop and test theories of academic entrepreneurship, as well as efforts to develop public policy and university management based solely on the examination of inventions disclosed to universities.

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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 virtually all efforts to develop policy examine only entrepreneurial activity based on inventions disclosed to university administrators. If faculty efforts to commercialize their research; hold equity in businesses based on their academic activities; start companies; and license technologies that emerged from their academic activities is different for potentially patented inventions disclosed to university administrators than it is for the totality of these efforts, then research and public policy based on the analysis of samples of inventions disclosed to university administrators is potentially biased.

This study tests the representativeness of efforts to predict four aspects of academic entrepreneurship: (1) commercialize research, (2) start companies, (3) hold equity in companies based on one's research, and (4) license technologies based on examination of faculty invention disclosures. Based on responses of 11,584 university professors to a survey of faculty in National Research Council ranked departments in Carnegie I and II universities, we find that these four aspects of academic entrepreneurship are systematically different for efforts based on inventions disclosed to university administrators than they are for all academic entrepreneurship effort. The demographic characteristics of the faculty entrepreneurs, the academic activities of those entrepreneurs, and their academic fields all differ.

Academics whose entrepreneurial efforts are based on inventions disclosed to universities are less likely to be male, and are younger than academics whose entrepreneurial efforts are not based on inventions disclosed to universities. Moreover, academics whose entrepreneurial efforts are based on inventions disclosed to universities are more likely to trade off research and teaching time when engaging in their entrepreneurial activities than academics whose efforts are not based on inventions disclosed to universities. Finally, academics whose entrepreneurial activities are based on disclosed inventions are affiliated to a different set of departments than academics whose entrepreneurial activities are not based on disclosed inventions. In particular, professors in biology, chemistry and materials science departments are disproportionately likely to engage in entrepreneurial activities based on disclosed inventions, professors in mechanical and civil engineering, computer science and economics are disproportionately likely to engage in entrepreneurial activities not based on disclosed inventions.

These findings have implications for efforts to understand academic entrepreneurship. First, we may be greatly underestimating both the depth and breadth of entrepreneurial

activity. Much more academic entrepreneurship exists than takes the form of academic entrepreneurship to exploit university assigned intellectual property. That is, the extent of this activity is much greater than our estimates of it.

We might also be underestimating the breadth of academic entrepreneurship by focusing attention on the commercialization of university assigned inventions. Academic entrepreneurship can take a variety of forms that exploit the outputs of teaching as well as research and consulting on the basis of knowhow rather than specific inventions. Most efforts underestimate this breadth of entrepreneurial activity because of their focus on university intellectual property. Even the few previous studies that have focused on a more heterogeneous set of entrepreneurial activities, such as Louis et al. (1989), Agrawal and Henderson (2002), Thursby and Kemp (2002), Gulbrandsen and Smeby (2005) and Jensen et al. (2007) tend to examine the narrow set of academic fields in which university research can be patented or make their analysis conditional on the possession of a university-assigned patent. Academic entrepreneurship might take very different forms when university assigned IP is not a condition for it.

Second, our findings explain the mismatch between theory and empirical findings in this area. Intellectual property based approach to sample selection maps poorly to the arguments made in a number of theoretical papers. A number of theoretical articles predict entrepreneurial activity by academics in ways not predicated on the university intellectual property rights (Aghion et al. 2005, Lacetera 2007). For instance, career cycle theories of academic entrepreneurship (Thursby et al. 2007) are based on faculty members' age and career status and not the potential to appropriate returns from that research through patents. Therefore, efforts to test career cycle theories might fail to yield results consistent with the theory or might yield results that overstate the effects of the theory because of sample selection bias.

Third, 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. Scholars investigating such issues as the individual and school-level determinants of the decision to patent one's own research (Mowery, Sampat and Ziedonis, 2002; Coupe, 2003; Owen-Smith, 2003; Calderini, Franzoni and Vezzulli, 2007); the rate of creation of spinoff companies across universities (Wright, Birley, Mosey, 2004; O'shea, Allen, Chevalier and Roche, 2005); the interaction between academic inventors and technology transfer offices (Shane 2002; Friedman, and Silberman, 2003; Macho-Stadler, Pérez-Castrillo and Veugelers, 2007); the impact of ways of organizing technology transfer offices (Siegel, Waldman and Link, 2003; Siegel, Waldman, Atwater and Link 2004); and collaborative research between companies and

universities on academic entrepreneurship (Berkowitz and Feldman, 2008); and whether academic entrepreneurship is a complement to or substitute for high quality research and teaching (Azoulay et al. 2006, Breschi et al. 2004, Goldfarb et al. 2007).

However, in the vast majority of these studies, sample selection is based on university intellectual property, whether the specific selection criterion is invention disclosures, patent applications, patent grants, licenses or company formation to exploit university-assigned inventions. Because of the distribution of university intellectual property across technical fields, analyses also tend to be focused on a narrow subset of departments, especially in the life sciences, where patenting is an effective way to protect intellectual assets (Cohen et al. 2000).

These findings also have implication 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, might be targeting only a part of the entrepreneurial activities that academics undertake, while leaving out an important subset of them. Furthermore, efforts to facilitate the entrepreneurial activities of academics through activities of technology transfer offices, as is currently the practice, might fail to help a sizeable portion of academic entrepreneurs. 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.

The remainder of this paper is organized as follows. In Section 1, we describe the survey instrument, and describe the collected data. In Section 2, the collected data are analyzed. Section 3 discusses the results and offers concluding remarks. All tables and figures are gathered in the Appendix.

1. The data

1.1 The Survey

This study is based on a survey that was administered to 58,321 tenured or tenure track faculty members and post doctoral researchers at all Carnegie I and II categorized universities (except Case Western Reserve University) in National Research Council tracked departments during the second half of 2007. The departments were drawn from four groups, as categorized by the National Research Council:

- Biological Sciences: Biochemistry and Molecular Biology; Cell and Developmental Biology; Ecology, Evolution, and Behavior; Molecular and General Genetics; Neurosciences; Pharmacology; Physiology.
- Engineering: Aerospace Engineering, Biomedical Engineering, Chemical Engineering, Civil Engineering, Electrical Engineering, Industrial Engineering, Materials Science, Mechanical Engineering.
- Physical Sciences and Mathematics: Astrophysics and Astronomy, Chemistry, Computer Sciences, Geosciences, Mathematics, Oceanography, Physics, Statistics and Biostatistics.
- Social and Behavioral Sciences: Anthropology, Economics, Geography, History, Political Science, Psychology, Sociology.

The survey was administered electronically. To obtain email addresses for all respondents, three undergraduate students collected addresses 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.

The questionnaire encompassed three main sections. The first section gathered demographical information: gender, age, academic rank, tenure at one's current institution, length of employment as an academic, university, and department. The second section examined the activities of the academics during the 2006-2007 academic year. It explored the faculty member's amount and the source of research funding, the level of interaction with institutions and industry, publication record, and the time allocation of academic work. The final section focused on entrepreneurial activities. We gathered information on invention disclosures, US patents, new business started based on patents, inventions licensed to others, new businesses created, and equity held in companies based on the academic's research and overall.¹

At the close of data collection, we had received 11,584 responses, yielding a 20 percent response rate. This response rate is consistent with that of similar surveys of academic researchers, in which participation is voluntary. To assess whether the 20 percent of respondents are representative of the overall population, we compared the distribution

¹ 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 individual's 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.

of respondents and non-respondents by school and department. The differences appear to be small, as Figure 1 shows.²

[Figure 1 about here]

1.2 Data Description

Tables 1 and 2 report some basic descriptive statistics on the characteristics of the respondents and of the entrepreneurial activities (if any) they have undertaken.

About 78% of the respondents were males. The most represented age categories are between the 30 and the 60, with an average and median age being approximately 49 years old. Only a small minority of respondents were younger and older. The majority of respondents have at least ten years of experience in academia at the time of participation in the survey, and about 70 percent of the respondents hold tenured positions.

We explored a number of entrepreneurial activities: disclosure of inventions; patenting of inventions; starting companies based on his/her patented inventions; the holding of equity in a company which was started based on his/her research; and the starting of companies whether based on his/her patented inventions or not. Most academics do not engage in entrepreneurial activities. Only about 36% of the sample has ever undertaken any of these activities in their academic careers.

At first glance, the focus on invention disclosures as the definition of the sampling frame for academic entrepreneurship might make sense. The most common of the entrepreneurial activities that we explored is the disclosure of inventions (25%), followed by patenting (19%) and then by starting new firms (16%).

However, such an assumption is contradicted by information on the types of new companies that the academics have started. The majority of academics who start new firms do not do it based on formal intellectual property. Overall, 11% of the respondents have started a company that is not based on a patented invention, as compared to 5% of the respondents that have started a company based on a patented invention. Anecdotal information provided by the respondents indicates a number of reasons why academics started companies that are not based on patented inventions. First, some faculty members wanted to preserve the intellectual property as a trade

² In future iterations of the paper, we plan to examine differences across other observable characteristics, including gender, academic rank and age, and also to employ correction techniques such as Inverse Probability Weighting (see Chay et al. 2008) to correct for non-randomness of the sample.

secret and invention disclosure would make trade secrecy impossible. Second, some faculty members did not want the university involved in the process of starting a company and so did not disclose. Third, some faculty members did not believe that a patent would be valuable enough to justify the cost of obtaining it. Fourth, some faculty members did not come up with knowledge that met the patent office criteria for patentability, such as non-patentable software or knowhow.

The distribution of disclosures, patents, and companies started by each respondent is highly skewed, with a few outliers who are heavily engaged in these activities. Figure 2 shows the distributions. Because of this high skewness (and the possibility of reporting/recalling errors and biases), we limit our analysis to dichotomous variables for whether an individual has been involved in any given entrepreneurial activity or not. Thus, our different measures of entrepreneurial activities will be the following dummies: whether any entrepreneurial activity (among those considered here) was undertaken, whether the respondents have disclosed inventions, whether they have patented, whether they hold equity in a company that uses their research, and whether they have started a business based on their research. Within this last category, we distinguished between business started on a patent and business started not based on a patent.

Just as the frequencies of entrepreneurial activities are skewed in the sample, so are the frequencies of publication and the availability of research funds. The average respondent had published 53 articles at the time of the survey, and had about \$260,000 of research funds available for the year 2006-7, but there were respondents with hundreds of publications and with several millions of dollars of available research funds.

Of these research funds, on average respondents report that about 6.5 % come from for-profit companies, a share very close to the NSF estimate of industry funding of academic research (NSF 2005). Interactions with industry people is limited to, on average, 2.4% of a scientist's time, while teaching and research occupy, respectively, 35.3% and 26.2% of the respondents' time, with, again, a wide variation in the sample.

[Tables 1 and 2 about here]

[Figure 2 about here]

2. Data Analysis

2.1 Descriptive analysis

The focus of our analysis lies in documenting whether IP-based entrepreneurial activities undertaken by academics correlate with different individual and institutional characteristics than non-IP-based entrepreneurial activities.

The descriptive evidence reported in Figures 3, 4 and 5, suggests that IP-based entrepreneurial activities, such as disclosing inventions, patenting, licensing, and founding companies based on a patent (and to a lesser extent holding equity) are correlated with certain individual and institutional characteristics and are clustered in certain academic departments. On the other hand, non-IP based entrepreneurial activities correlate differently with the individual and institutional characteristics and are clustered in different academic departments.

Among individual characteristics, the age and gender of academics is associated with different types of entrepreneurial activities. Figure 3 shows the age distribution (divided in six categories) of all the respondents, and among the respondents who declared to be involved in each of the entrepreneurial activities. Compared to the whole sample, the age distribution of academic entrepreneurs is shifted to the right, i.e. academics seem to avoid entrepreneurial endeavors early in their careers. This is consistent with a few theoretical analyses of scientists' activities though their life cycle (since we just have a cross section, however, we cannot test properly for age or tenure profiles).³ However, the relationship between age and entrepreneurial activities is not the same for entrepreneurial activities based on IP and not based on IP. Junior academics are more involved in entrepreneurial activities that are not based on patented inventions than entrepreneurial activities based on patented inventions. Figure 4 provides similar evidence by looking at the fraction of academics undertaking each of the entrepreneurial activities considered, by age, tenure, and academic rank. The shares of professors disclosing and patenting reaches a peak at an early age and career stage (with the notable exclusion of chaired professors) than the shares of professors holding equity in a company based on his/her research or starting a business not based on a patent.

[Figures 3 and 4 about here]

Figure 5 reports first the distribution of respondents across the 26 departments, and then the distributions conditional on undertaking specific entrepreneurial activities. The differences between the distribution of academics who start businesses not on a patent and the other academic entrepreneurs are striking. For example, while respondents who commercialize their research through IP-based mechanisms are

³ Levin and Stephan (1991), Lacetera (2007), Thursby et al. (2007)

clustered in biology, chemistry and materials science departments, non-IP based activities are more prevalent in mechanical and civil engineering departments, as well as in computer science and economics.

[Figure 5 about here]

Further evidence on the presence of very distinct entrepreneurial processes in academia comes from the analysis reported in Table 3. Here we report the frequency of each activity across the respondents, as well as 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. While the majority of academics who have disclosed inventions, patented, held equity in a business based on their research or have started a business based on a patent have also performed at least one of these other activities, those who have started a business not based on a patent tend not to have engaged in any of these other activities. This is not surprising, given that most academics who have licensed or have started companies based on their patented inventions tend to be exploiting technologies assigned to their universities, and starting a business based on a patented invention tends to also involve licensing that invention, which was previously disclosed. However, it does illustrate that the implicit model employed by researchers and policy makers exploring academic entrepreneurship (research leads to invention disclosure, which leads to licensing and the formation of new companies) is correct for only some types of academic entrepreneurship. And that type of academic entrepreneurship is not representative of other types.

[Table 3 about here]

2.2. Regression Analysis

The analyses reported in tables 7, 8, 9 and 10 test for the robustness to regression specifications of the patterns described in the previous section. Each table shows the regression of our different dichotomous measures of entrepreneurship on the same set of variables. The last column of each table limits the analysis to only those respondents who have started a business, and analyzes the determinants of the probability of starting a business on a patent as opposed to not on a patent.⁴ We first regress the

⁴ Since there are 138 instances in which a respondent has started both businesses on patents and not on patent, the dummy variables for starting business on patent and not on patent are not perfectly mutually exclusive. As a consequence, regressing one of two dummies on the explanatory variables limited to the sample of those who started a business, or regressing the other dummy, is not a neutral decision, i.e. results would not be perfectly symmetric. In unreported analyses, we “reversed” the dependent variable and regressed a dummy variable for starting a business not on patent on the covariates. While not perfectly symmetric to the reported regression, the coefficient estimates have the opposite sign and very similar absolute values than those reported in the last column of each regression table in the Appendix.

different measures of entrepreneurial activities on gender and age.⁵ Then we add the number of publications at the time of the survey, and the amount of research funds secured in the 2006-7 year. Both of these variables are expressed in logarithmic terms (more precisely, by the natural log of the variable+1) since their distribution is highly non-normal. We then add variables related to the portion of time the respondents spend in research, teaching, and meeting with industry, the share of funding coming from business sources, and department dummies. Finally, we control for the university where the respondents are affiliated by adding school fixed effects. We employ OLS or linear probability models. Results from logit specification convey the same results.

[Tables 7, 8, 9 and 10 about here]

The regressions analyses confirm most of the descriptive evidence, and point to a number of additional findings. First, male academics are consistently more likely than their female colleagues to engage in entrepreneurial activities of any sort. Once more covariates are added to the analysis, however, the coefficient estimate on gender, while still significantly positive, is smaller, indicating that most of the “advantage” of being male is associated to having more research funds, higher research productivity, and by the gender composition of the departments. However, in the fully specified model, there are no significant gender differences between academics that start a business on patent versus those who don’t, nor are there gender differences between scholars starting a business on a patent or not on a patent.

The coefficient estimate on the dummies indicating the age categories are remarkably similar for different dependent variables, but given the higher share of respondents engaging especially in patenting and disclosing, these estimate indicate that differences across age groups are smaller for these activities, and in particular that junior faculty are at less disadvantage. Furthermore, in more specified models the age dummies lose much of their explanatory power and this is largely due, again, to the impact of research funding and publication records and their correlation with age. Again, respondents having a business not based on a patent appear different from the other academic entrepreneurs, since the age profile is unchanged and the age dummies are still significant, confirming the descriptive evidence of the non-patent-based entrepreneurs being distributed more toward older ages.

In general, higher scientific productivity, availability of research funds, the share of funds coming from industry, and the intensity of the interactions with industry are all

⁵ The age group variable is highly collinear with the variables indicating academic rank and tenure. These variables are therefore omitted from the regression analysis, but, as also noted in the descriptive analysis, they show similar relationships with entrepreneurial activities.

positively and significantly correlated with any type of entrepreneurial activity. In some specifications, scientific productivity as expressed by publications is negatively correlated with the probability of starting a business not on a patent, though these effects fade away in fully specified models.

More importantly, the patterns are different for the kind of start-ups created. While starting a business on a patent, and patenting, disclosing and holding equity seem to take away time from research and teaching activities (or to involve individuals who spend less time in these activities), this tradeoff is not present for those who start a business not based on a patent. There is, in particular, a consistently positive relationship with the share of time spent teaching.⁶ This may indicate that the source of the academic's value that justifies business formation for non-patent based start-ups lies in teaching as well as research.⁷

The introduction of department dummies increases the overall explanatory power of the models, and confirms the different patterns, in terms of departmental affiliation, of different forms of entrepreneurship. For reasons of space and clarity, we do not report the coefficient estimates on the departmental dummies in the regression tables. Instead, we offer a separate analysis of the department effects in figures 6 to 11. In each figure, the reported columns indicate the coefficient estimates on a given department dummy, in a model that includes gender, age categories, publication records and research funding.⁸ The estimates are odds ratios (from which we subtract 1) from a logit model.⁹ Only statistically significant estimates are reported, while insignificant estimates are set at zero. Negative values indicate a lower probability of being in a given department as compared to the omitted category (Aerospace engineering). Again, the departmental distribution of entrepreneurs engaging in non-IP based companies stands out as markedly different from the other cases. Biology, biomedical Engineering and Materials science emerge as the departments where invention disclosures, patenting, and to a lesser extent starting businesses based on a patent are more likely to occur. Business started not on a patent, instead, are more likely in such departments as Civil and Mechanical Engineering, and Computer Science.

⁶ Since we do not have information about the total amount of time worked by each respondent (say in a week), we cannot conclude that the total time spent in research and teaching is smaller for certain types of entrepreneurs, and these may in fact work longer hours than their colleagues.

⁷ If this proved to be true, it would likely make many deans and provosts very happy.

⁸ We chose this model because it maximizes the number of observations while having enough control variables. Other specifications convey similar results.

⁹ We used a logit model because the odds ratios are more easily comparable across different models with different dependent variables.

In addition, while a large number of departments differ for some activities, particularly disclosures and patenting (but also holding equity), the distribution of businesses started not on a patent is more homogenous across disciplines.¹⁰ The lesser heterogeneity for non-patent based start-ups highlights the problem of a focus on patent-based academic entrepreneurship. It leads to a focus on a small number of academic fields, under the assumption that they are where “the action lies”. One can imagine the problem that this creates, not just for academic researchers seeking to understand academic entrepreneurship, but for provosts concerned with university contributions to economic development or generating private wealth for the university when making resource allocation decisions across departments. The provosts might falsely concentrate resources based on inaccurate understanding of the distribution of entrepreneurial activities.

[Figures 6 to 11 about here]

The introduction of school dummies (not reported in the tables) also increase the portion of explained variance of the entrepreneurship measures, and the dummies are jointly significant in general. The estimates on the other coefficients are not significantly affected by the introduction of school fixed effects.

3. Discussion and conclusion

The evidence analyzed in this paper is mostly descriptive and, given the cross-sectional nature of the data, strong causal implications cannot be drawn. However, the size of the sample and its representativeness across schools and departments, the variety of measures of entrepreneurial activity used, and the different empirical specifications implemented, lend robustness and credibility to the key finding of this study: a sizeable portion of academic entrepreneurs engage in types of commercial activities that traditional measures, such as the transfer of formal IP rights, do not capture. Moreover, the academics who undertake non-patent based entrepreneurial activities are not well represented by their colleagues engaging in patent based entrepreneurial activities. The differences lie in the demographics of the entrepreneurs (gender and age); the activities of the entrepreneurs (particularly the tradeoff between entrepreneurial activities on the one hand, and research and teaching on the others); and the set of the departments in which they are found.

¹⁰ The coefficient estimate on the dummies for “similar” departments, i.e. departments from which, in theory, we would expect similar rates of entrepreneurial activities, are remarkably similar in most cases. For example the estimate on the following pairs of departments: Economics and Geography, Anthropology-Sociology and Political Science, chemistry and chemical engineering, and Civil and Industrial engineering, have very similar estimates.

These findings have implications for efforts to understand academic entrepreneurship. First, we may be greatly underestimating both the depth and breadth of entrepreneurial activity. Much more academic entrepreneurship exists than takes the form of academic entrepreneurship to exploit university assigned intellectual property and this effort takes a wide variety of forms. Second, efforts to test theories of academic entrepreneurship might yield better results than they have to date if they were based on samples of all academic entrepreneurs, rather than just those that exploit patented inventions. Third, 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.

Our findings also have implication 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, might be targeting only a part of the entrepreneurial activities that academics undertake, while leaving out an important subset of them. Furthermore, efforts to facilitate the entrepreneurial activities of academics through activities of technology transfer offices, as is currently the practice, might fail to help a sizeable portion of academic entrepreneurs. 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.¹¹

¹¹ We are planning additional work to be done in order to further reinforce our results and to investigate additional, related questions. As previously mentioned, we are in the process of providing further checks of the representativeness of the sample of respondents, and of elaborating techniques to correct for any non-randomness. We are also in the process of collecting additional data in order to better account for personal, institutional, and environmental characteristics. Further analysis will distinguish between public and private universities and universities of different ranks. Lach and Shankerman (2003), for example, find differences in the degree and patterns of (formal, IP-based) research commercialization activities in public and private universities, and we plan to contribute to these investigations by looking at the differences across types of commercialization activities. We also plan to check whether the strength of incentives to disclose and patent, as expressed by the different royalty rates for academic inventors in different universities, are related to the performance of different activities. Finally, we plan to assess whether different commercialization activities correlate with different geographical locations of universities, e.g. rural vs. urban locations, or locations within dense industrial clusters (such as the Silicon Valley or Massachusetts) versus more isolated locations.

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Appendix: Figures and Tables

Figure 1: Distribution of respondents and non-respondents by school and department

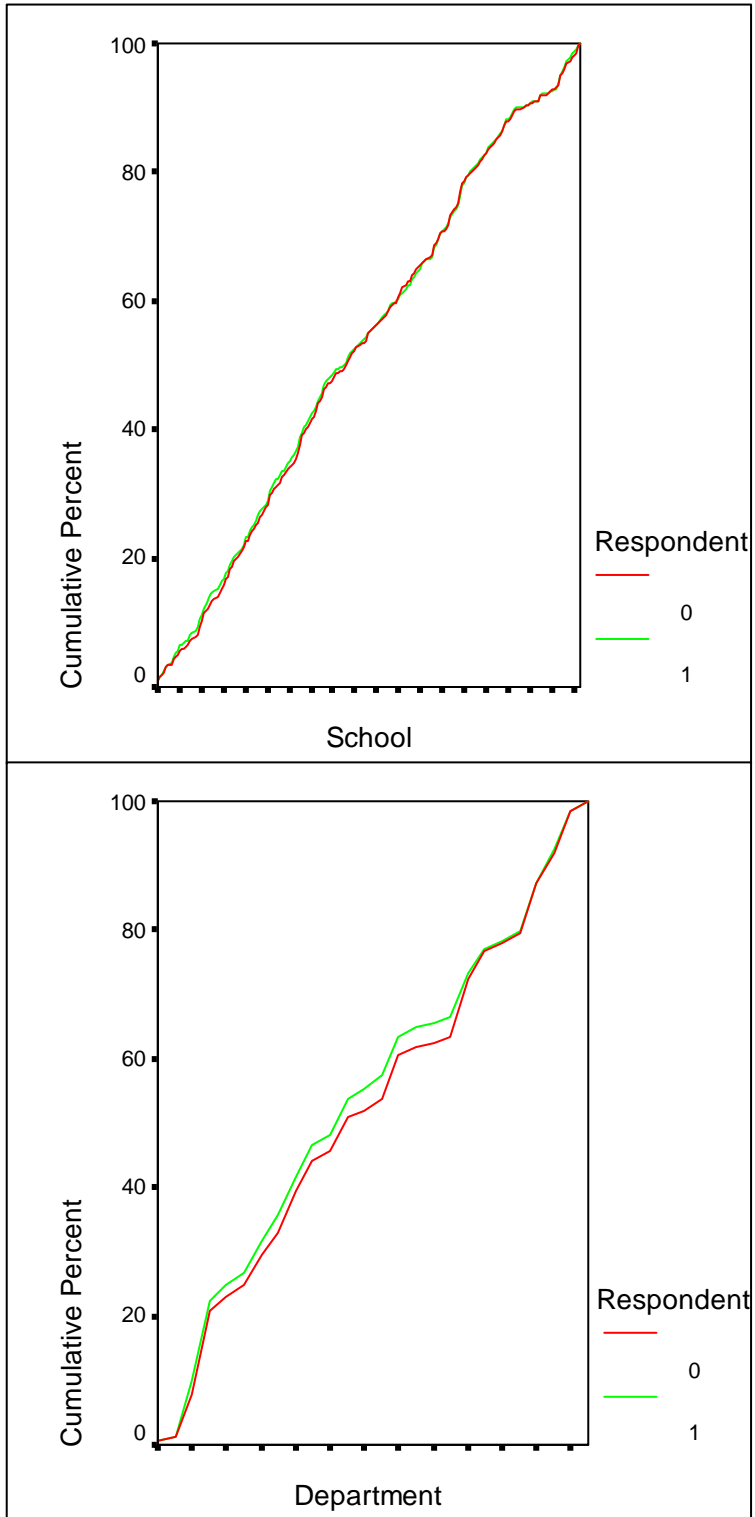


Table 1: Descriptive statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
<i>Included in the regression models</i>						
DEntrepr_overall	Dummy: 1 if at least one entrepreneurial activity	11,136	0.36	0.48	0.00	1.00
DDisclosure	Dummy: 1 if at least one disclosure (to respondent)	11,584	0.25	0.44	0.00	1.00
DPatent	Dummy: 1 if at least one US patent issued (to respondent)	11,313	0.19	0.39	0.00	1.00
DEquity	Dummy: 1 if respondents holds equity in company that uses his/her research)	11,210	0.09	0.28	0.00	1.00
DNewbusines	Dummy: 1 if at least one business started	11,584	0.16	0.36	0.00	1.00
DNewbusonpat	Dummy: 1 if at least one business started on patent	11,169	0.06	0.24	0.00	1.00
DNewbusnotonpat	Dummy: 1 if at least one business started on patent not on patent	11,169	0.11	0.32	0.00	1.00
Male	Dummy: 1 if respondent is male	11,584	0.78	0.42	0.00	1.00
Ln(academicarticle)	ln(Number of academic articles)	11,410	3.31	1.25	0.00	8.71
Ln(researchfunds)	ln(Total value of research funding (06-07))	10,992	8.82	5.16	0.00	17.97
Time in teaching	% of 06-07 time in teaching	8,543	35.31	20.80	0.00	100.00
Time in research	% of 06-07 time in researching	8,543	26.17	17.73	0.00	100.00
Time in meet indus	% of 06-07 time in meeting industry people	8,543	2.37	4.76	0.00	80.00
Founds profit com	% of 06-07 research founding from profit company	8,355	6.55	18.74	0.00	100.00
<i>Excluded from the regression models</i>						
NDisclosure	Number of disclosures (to you)	11,323	1.42	6.07	0.00	350.00
NPatent	Number of Us patents issued (to you)	11,314	0.95	4.40	0.00	131.00
NNewbusiness	Number of new business started (by you)	10,837	0.25	0.89	0.00	52.00
NNewbusonpat	Number of companies founded on patent (by you)	11,169	0.09	0.41	0.00	10.00
Academic articles	Number of academic articles published	11,410	53.30	94.14	0.00	6,080.00
Research funds	Total value of research funding (06-07)	10,992	285,816.88	1,121,758.16	0.00	64,000,000

Table 2: Descriptive statistics - categorical variables

Age	Frequency	Percent
20-29	175	1.54
30-39	2,685	23.68
40-49	3,109	27.42
50-59	3,179	28.04
60-69	1,897	16.73
70-79	294	2.59
Total	11,339	100.00
Years in Academia		
0-5	1,694	14.69
6-10	2,026	17.58
11-15	1,541	13.37
16-20	1,525	13.23
21-25	1,314	11.39
26+	3,429	29.74
Total	11,529	100.00
Academic rank		
Lecturer	335	2.89
Assistant Professor	2,697	23.28
Associate Professor without Tenure	357	3.08
Associate Professor with Tenure	2,609	22.52
Full Professor	4,612	39.81
Professor with Endowed Chair	972	8.39
Other	2	0.02
Total	11,584	100.00
Gender		
Female	2,568	22.17
Male	9,016	77.83
Total	11,584	100.00

Figure 2: Distribution of entrepreneurial activities

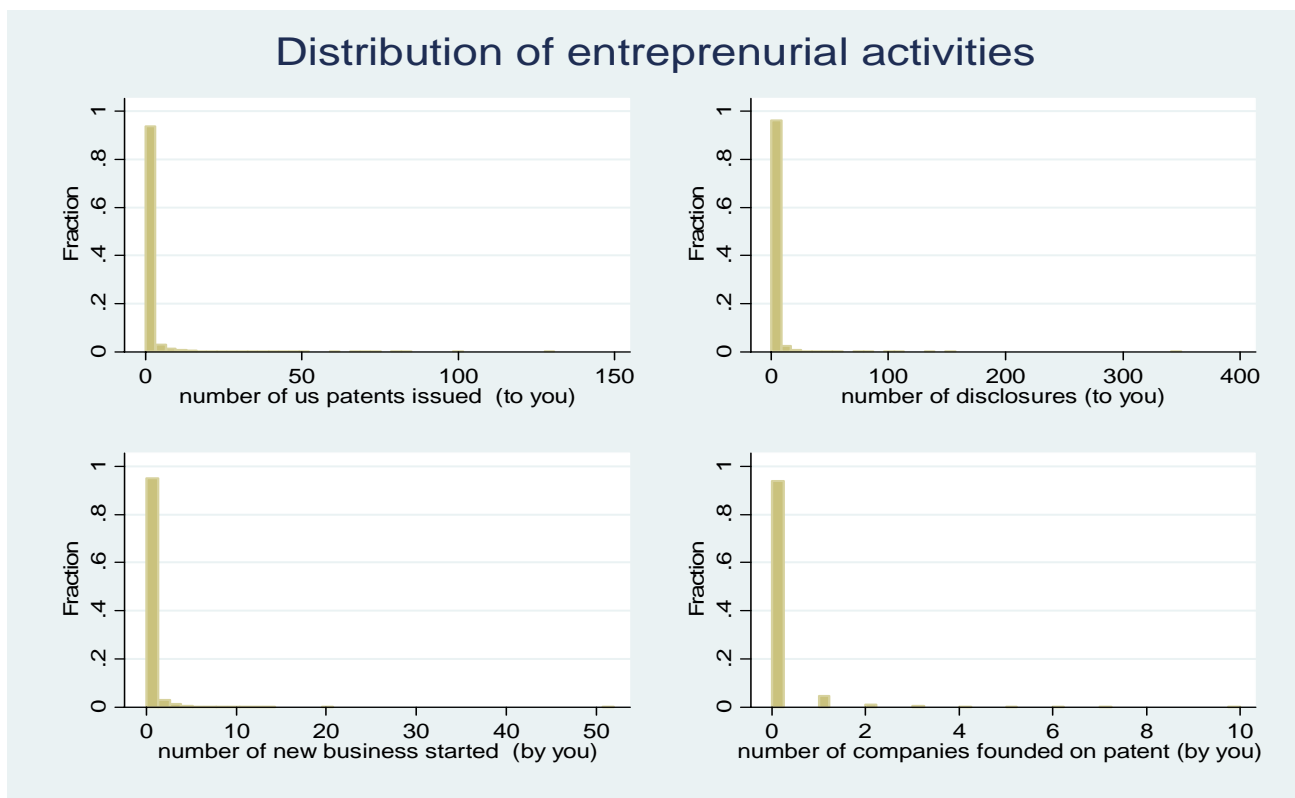
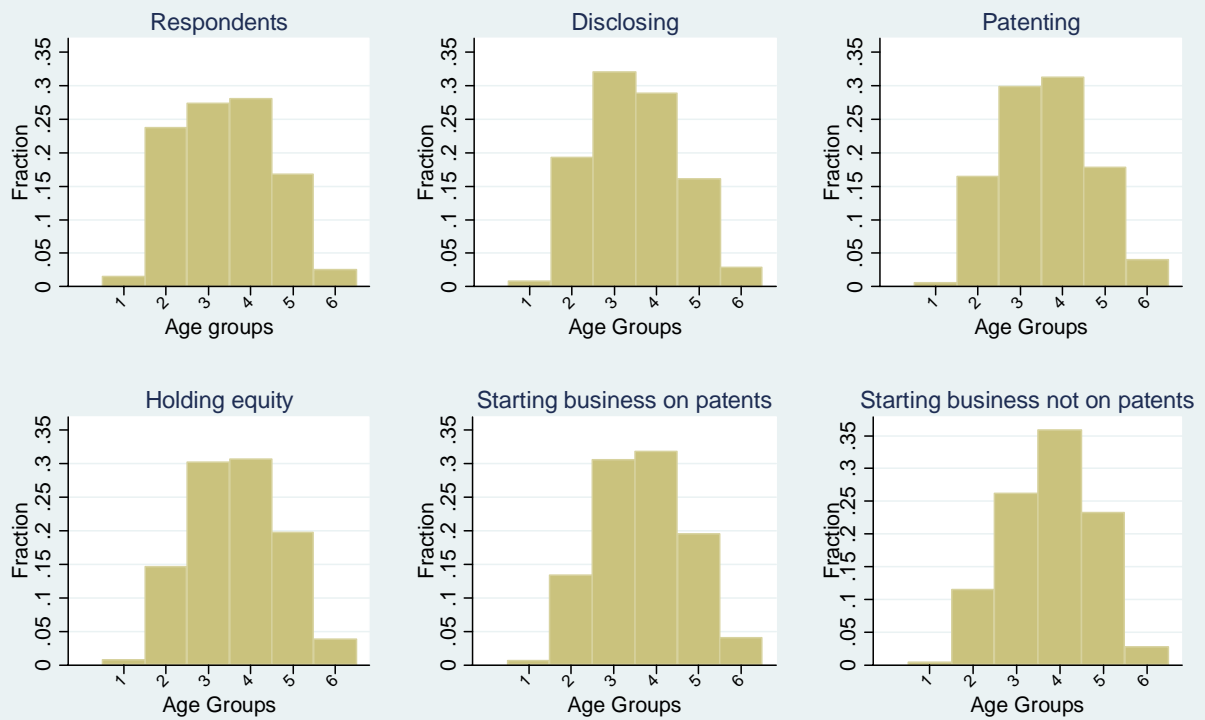


Table 3: Frequency of entrepreneurial activities

	Frequency					
	Tot	Only activity	In conjunction with			
Disclosure			Patent	Equity	New business on patent	
Disclosure	2,944	793				
Patent	2,166	182	1,822			
Equity	957	49	691	611		
New business on patent	682	13	610	560	493	
New business not on patent	1,266	632	432	314	343	138

Distribution of respondents across age groups overall and by entrepreneurial activity



Age groups reported (see legend below)

Figure 3: Distribution of entrepreneurial activities across age groups. Legend: 1: 20-29; 2: 30-39; 3: 40-49; 4: 50-59; 5: 60-69; 6: 70+

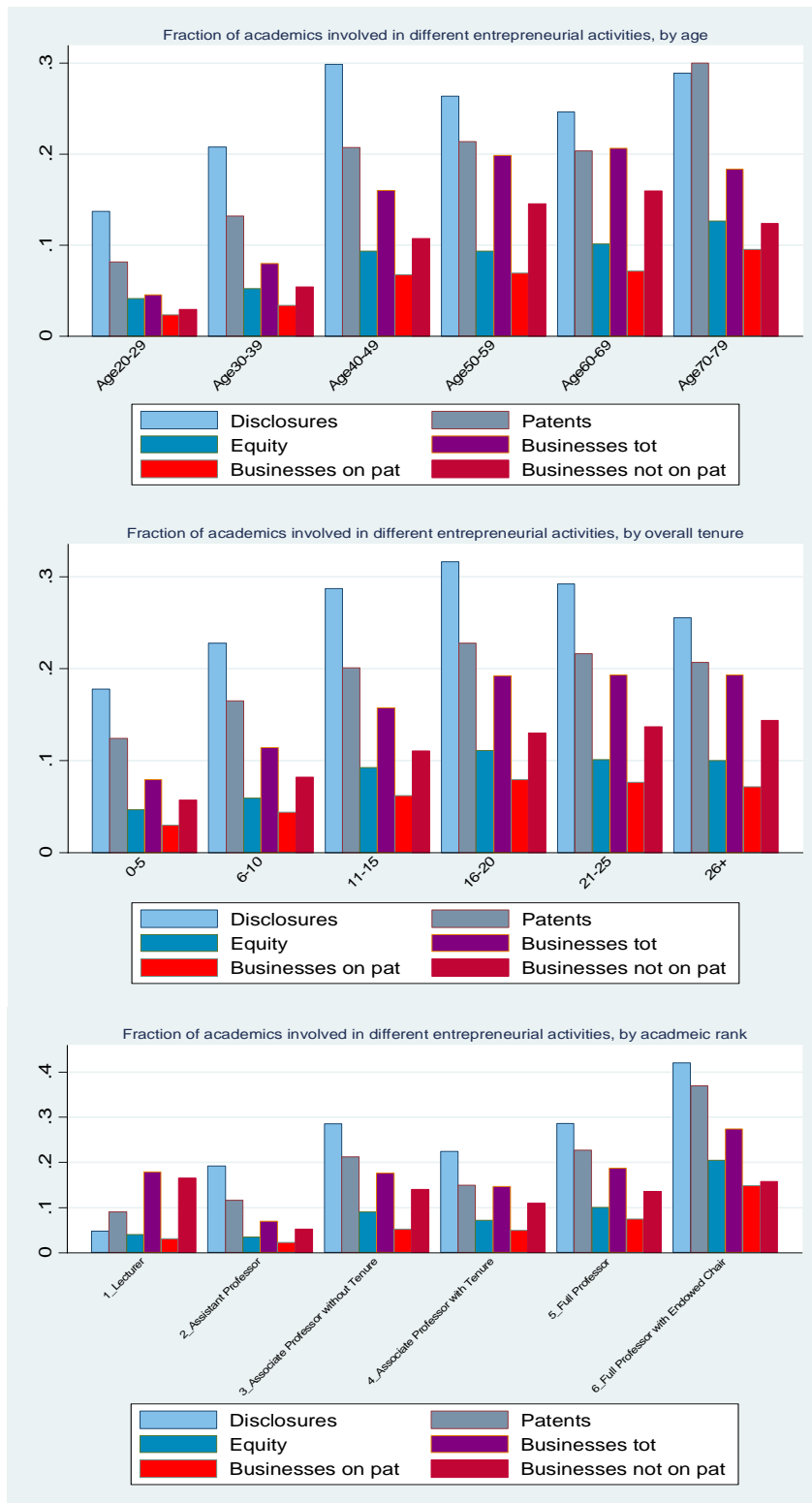


Figure 4: Fraction of academics involved in different entrepreneurial activities, by age, by tenure and by academic rank

Distribution of respondents across departments

overall and by entrepreneurial activity

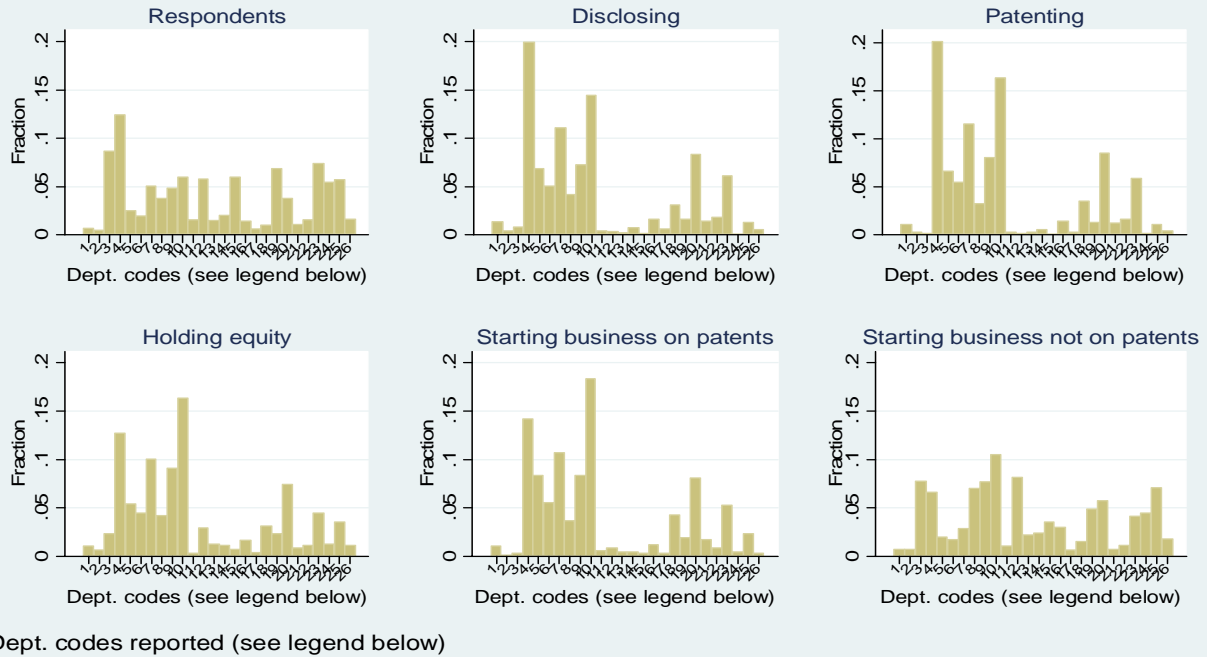


Figure 5: Distribution of respondents and entrepreneurs among departments. Legend:

Code	Department	Code	Department
1	Aerospace Engineering	14	Geology
2	Agricultural Sciences	15	History and other humanities
3	Anthropology and Sociology	16	Industrial and Manufacturing Engineering
4	Biology and Biochemistry	17	Marine Sciences
5	Biomedical Engineering	18	Materials Science
6	Chemical Engineering	19	Mathematics
7	Chemistry	20	Mechanical Engineering
8	Civil Engineering	21	Neuroscience
9	Computer and Electrical Engineering	22	Pharmacy
10	Computer Science	23	Physics and Astronomy
11	Ecology and Evolution	24	Political Science
12	Economics and Agricultural Economics	25	Psychology
13	Geography	26	Statistics

Correlation tables

Table 4

Variable		1	2	3	4	5	6	7	8	9	10	11	12
DDisclosure	1	1.000											
DPatent	2	0.675	1.000										
DEquity	3	0.322	0.349	1.000									
DNewbusines	4	0.254	0.262	0.502	1.000								
DNewbusonpat	5	0.374	0.418	0.600	0.580	1.000							
DNewbusnotonpat	6	0.071	0.057	0.248	0.813	0.072	1.000						
Male	7	0.139	0.146	0.113	0.117	0.095	0.087	1.000					
Ln(academicarticle)	8	0.336	0.323	0.205	0.152	0.203	0.054	0.276	1.000				
Ln(researchfunds)	9	0.301	0.244	0.150	0.101	0.152	0.025	0.069	0.371	1.000			
Time in teaching	10	-0.211	-0.173	-0.129	-0.057	-0.112	0.007	-0.070	-0.363	-0.446	1.000		
Time in research	11	-0.253	-0.223	-0.112	-0.107	-0.123	-0.057	-0.043	-0.083	-0.107	-0.383	1.000	
Time in meet indus	12	0.223	0.218	0.257	0.269	0.200	0.196	0.106	0.143	0.129	-0.180	-0.173	1.000
Founds profit com	13	0.213	0.214	0.175	0.193	0.189	0.110	0.090	0.120	0.070	0.014	-0.155	0.304

Table 5

Variable		1	2	3	4	5	6
DDisclosure	1	1.000					
DPatent	2	0.674	1.000				
DNewbusonpat	3	0.376	0.419	1.000			
DNewbusnotonpat	4	0.071	0.057	0.070	1.000		
DNewbusines	5	0.257	0.271	0.579	0.813	1.000	
DEquity	6	0.316	0.344	0.601	0.248	0.516	1.000

Table 6

Variable		1	2	3	4	5	6
Academic articles	1	1.000					
Log(academicarticle)	2	0.574	1.000				
Ln(academicarticle)	3	0.574	1.000	1.000			
Research founds	4	0.137	0.180	0.180	1.000		
Log(researchfounds)	5	0.195	0.371	0.371	0.256	1.000	
Ln(researchfounds)	6	0.195	0.371	0.371	0.256	1.000	1.000

Regression results

Table 7

Explanatory variables	Dependent variables							
	DEntrepr_overall	DDisclosure	DPatent	DNewbusines	DEquity	DNewbusonpat	DNewbusnotonpat	DNewbusonpat (cond on starting a business)
Male	0.179*** (0.01)	0.146*** (0.01)	0.129*** (0.01)	0.0907*** (0.01)	0.0714*** (0.01)	0.0505*** (0.01)	0.0544*** (0.01)	0.159*** (0.04)
Age30-39	0.0816** (0.04)	0.0604* (0.03)	0.0412 (0.03)	0.0277 (0.03)	0.00585 (0.02)	0.00696 (0.02)	0.021 (0.02)	-0.0563 (0.17)
Age40-49	0.201*** (0.04)	0.145*** (0.03)	0.111*** (0.03)	0.104*** (0.03)	0.0440** (0.02)	0.0382** (0.02)	0.0717*** (0.02)	-0.0702 (0.17)
Age50-59	0.200*** (0.04)	0.103*** (0.03)	0.111*** (0.03)	0.138*** (0.03)	0.0405* (0.02)	0.0375** (0.02)	0.107*** (0.02)	-0.137 (0.17)
Age60-69	0.176*** (0.04)	0.0730** (0.03)	0.0897*** (0.03)	0.138*** (0.03)	0.0419* (0.02)	0.0355* (0.02)	0.116*** (0.03)	-0.151 (0.17)
Age70-79	0.199*** (0.05)	0.107*** (0.04)	0.178*** (0.04)	0.110*** (0.03)	0.0632** (0.03)	0.0560** (0.02)	0.0773** (0.03)	0.00294 (0.18)
Constant	0.0581 (0.040)	0.0448 (0.030)	-0.000621 (0.030)	-0.0118 (0.030)	-0.00379 (0.020)	-0.00833 (0.020)	-0.00484 (0.020)	0.341** (0.170)
Observations	10,971	11,339	11,142	11,339	11,039	11,002	11,002	1,782
prob>F	0	0	0	0	0	0	0	0
F test	74.74	49.69	53.97	56.77	30.34	22.86	38.98	5.38
R-squared	0.039	0.03	0.03	0.029	0.016	0.01	0.02	0.02

*** p<0.01, ** p<0.05, * p<0.1; Linear probability OLS models; Standard errors in parentheses

Table 8

Explanatory variables	Dependent variables							DNewbusonpat (cond on starting a business)
	DEntrepr_overall	DDisclosure	DPatent	DNewbusines	DEquity	DNewbusonpat	DNewbusnotonpat	
Male	0.107*** (0.01)	0.0651*** (0.01)	0.0638*** (0.01)	0.0751*** (0.01)	0.0439*** (0.01)	0.0266*** (0.01)	0.0591*** (0.01)	0.0195 (0.04)
Age30-39	0.00417 (0.04)	-0.0211 (0.03)	-0.0333 (0.03)	0.00855 (0.03)	-0.0257 (0.02)	-0.02 (0.02)	0.0247 (0.03)	-0.166 (0.16)
Age40-49	0.0557 (0.04)	-0.0162 (0.03)	-0.0283 (0.03)	0.0702** (0.03)	-0.0153 (0.02)	-0.0134 (0.02)	0.0818*** (0.03)	-0.258 (0.16)
Age50-59	0.0419 (0.04)	-0.0809** (0.03)	-0.0506* (0.03)	0.106*** (0.03)	-0.0273 (0.02)	-0.0221 (0.02)	0.127*** (0.03)	-0.343** (0.16)
Age60-69	0.0308 (0.04)	-0.0973*** (0.03)	-0.0659** (0.03)	0.113*** (0.03)	-0.0259 (0.02)	-0.0225 (0.02)	0.141*** (0.03)	-0.346** (0.16)
Age70-79	0.0473 (0.05)	-0.0672 (0.04)	0.0144 (0.04)	0.0831** (0.04)	0.00365 (0.03)	-0.00551 (0.02)	0.106*** (0.03)	-0.232 (0.17)
Ln(academicarticle)	0.0816*** (0.00)	0.0983*** (0.00)	0.0831*** (0.00)	0.0157*** (0.00)	0.0354*** (0.00)	0.0310*** (0.00)	-0.0114*** (0.00)	0.130*** (0.01)
Ln(researchfounds)	0.0162*** (0.00)	0.0159*** (0.00)	0.0108*** (0.00)	0.00585*** (0.00)	0.00482*** (0.00)	0.00417*** (0.00)	0.00289*** (0.00)	0.0142*** (0.00)
Constant	-0.164*** (0.040)	-0.204*** (0.030)	-0.186*** (0.030)	-0.0722** (0.030)	-0.0843*** (0.020)	-0.0791*** (0.020)	-0.00886 (0.030)	0.0265 (0.160)
Observations	10,486	10,762	10,642	10,762	10,533	10,509	10,509	1,722
prob>F	0	0	0	0	0	0	0	0
F test	196.41	250.4	194.23	59.4	73.44	69.03	31.49	42.6
R-squared	0.13	0.16	0.13	0.042	0.053	0.05	0.02	0.17

*** p<0.01, ** p<0.05, * p<0.1; Linear probability OLS models; Standard errors in parentheses

Table 9

Explanatory variables	Dependent variables							DNewbusonpat (cond on starting a business)
	DEntrpr_overall	DDisclosure	DPatent	DNewbusines	DEquity	DNewbusonpat	DNewbusonotpat	
Male	0.0536*** (0.01)	0.0323** (0.01)	0.0304** (0.01)	0.0484*** (0.01)	0.0263*** (0.01)	0.0129 (0.01)	0.0439*** (0.01)	-0.0174 (0.05)
Age30-39	0.0397 (0.04)	-0.00329 (0.04)	-0.0175 (0.04)	0.0233 (0.04)	-0.0139 (0.03)	-0.0262 (0.03)	0.0421 (0.03)	-0.232 (0.18)
Age40-49	0.0889** (0.04)	0.0142 (0.04)	-0.00954 (0.04)	0.0740** (0.04)	-0.00356 (0.03)	-0.0235 (0.03)	0.0914*** (0.03)	-0.259 (0.18)
Age50-59	0.113** (0.04)	-0.00948 (0.04)	-0.00397 (0.04)	0.106*** (0.04)	-0.0167 (0.03)	-0.0258 (0.03)	0.128*** (0.03)	-0.289 (0.18)
Age60-69	0.101** (0.05)	-0.00829 (0.04)	-0.0197 (0.04)	0.118*** (0.04)	-0.0153 (0.03)	-0.0161 (0.03)	0.145*** (0.03)	-0.276 (0.18)
Age70-79	0.183*** (0.06)	0.0753 (0.06)	0.127** (0.05)	0.103* (0.05)	0.0898** (0.04)	0.0148 (0.04)	0.121*** (0.05)	-0.159 (0.20)
Ln(academicarticle)	0.0397*** (0.01)	0.0523*** (0.01)	0.0541*** (0.01)	0.0167*** (0.01)	0.0318*** (0.00)	0.0272*** (0.00)	-0.00912* (0.01)	0.0659*** (0.02)
Ln(researchfounds)	0.0146*** (0.00)	0.0134*** (0.00)	0.00959*** (0.00)	0.0152*** (0.00)	0.00895*** (0.00)	0.00855*** (0.00)	0.00951*** (0.00)	0.00808 (0.01)
Time in teaching	-0.00234*** (0.00)	-0.00251*** (0.00)	-0.00211*** (0.00)	0.000311 (0.00)	-0.00102*** (0.00)	-0.000602** (0.00)	0.000833*** (0.00)	-0.00393*** (0.00)
Time in research	-0.00291*** (0.00)	-0.00299*** (0.00)	-0.00210*** (0.00)	-0.0000999 (0.00)	-0.000624** (0.00)	-0.000620** (0.00)	0.000138 (0.00)	-0.00477*** (0.00)
Time in meet indus	0.0130*** (0.00)	0.00529*** (0.00)	0.00608*** (0.00)	0.0167*** (0.00)	0.0111*** (0.00)	0.00664*** (0.00)	0.0115*** (0.00)	-0.00255 (0.00)
Founds profit com	0.00231*** (0.00)	0.00181*** (0.00)	0.00184*** (0.00)	0.00182*** (0.00)	0.00122*** (0.00)	0.00130*** (0.00)	0.000680*** (0.00)	0.00135*** (0.00)
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.248*** (0.09)	0.210** (0.08)	-0.00525 (0.08)	-0.221*** (0.08)	-0.107* (0.06)	-0.0693 (0.06)	-0.162** (0.07)	0.668*** (0.26)
Observations	6,092	6,213	6,175	6,213	6,117	6,091	6,091	1,088
prob>F	0	0	0	0	0	0	0	0
F test	76.58	88.47	66.89	28.5	27.23	24.81	15.5	12.63
R-squared	0.319	0.35	0.29	0.146	0.142	0.13	0.09	0.31

*** p<0.01, ** p<0.05, * p<0.1; Linear probability OLS models; Standard errors in parentheses

Table 10

Explanatory variables	Dependent variables							
	DEntrepr_overall	DDisclosure	DPatent	DNewbusines	DEquity	DNewbusonpat	DNewbusnotonpat	Dnewbusonpat (cond on start a business)
male7	0.0540*** (0.01)	0.0324** (0.01)	0.0311** (0.01)	0.0484*** (0.01)	0.0232** (0.01)	0.0111 (0.01)	0.0446*** (0.01)	-0.0323 (0.05)
Age30-39	0.0302 (0.04)	-0.00668 (0.04)	-0.0248 (0.04)	0.0265 (0.04)	-0.0172 (0.03)	-0.0263 (0.03)	0.041 (0.03)	-0.173 (0.20)
Age40-49	0.0831* (0.04)	0.0192 (0.04)	-0.0109 (0.04)	0.0731* (0.04)	-0.00617 (0.03)	-0.0241 (0.03)	0.0858*** (0.03)	-0.169 (0.20)
Age50-59	0.112** (0.05)	-0.0023 (0.04)	-0.00391 (0.04)	0.110*** (0.04)	-0.0156 (0.03)	-0.0248 (0.03)	0.126*** (0.03)	-0.201 (0.20)
Age60-69	0.0969** (0.05)	-0.00232 (0.04)	-0.0254 (0.04)	0.118*** (0.04)	-0.0169 (0.03)	-0.0191 (0.03)	0.144*** (0.04)	-0.205 (0.20)
Age70-79	0.173*** (0.06)	0.0804 (0.06)	0.117** (0.05)	0.105** (0.05)	0.0951** (0.04)	0.0216 (0.04)	0.114** (0.05)	-0.0269 (0.22)
Ln(academicarticle)	0.0378*** (0.01)	0.0477*** (0.01)	0.0491*** (0.01)	0.0172*** (0.01)	0.0309*** (0.01)	0.0261*** 0.00	-0.00678 (0.01)	0.0587*** (0.02)
Ln(researchfounds)	0.0141*** 0.00	0.0125*** 0.00	0.00799** 0.00	0.0154*** 0.00	0.00869*** 0.00	0.00803*** 0.00	0.0100*** 0.00	0.00883 (0.01)
Time in teaching	-0.00247*** (0.00)	-0.00249*** (0.00)	-0.00215*** (0.00)	0.0000172 (0.00)	-0.00110*** (0.00)	-0.000717*** (0.00)	0.000533* (0.00)	-0.00344*** (0.00)
Time in research	-0.00296*** (0.00)	-0.00302*** (0.00)	-0.00220*** (0.00)	-0.000189 (0.00)	-0.000725** (0.00)	-0.000706*** (0.00)	0.0000853 (0.00)	-0.00400*** (0.00)
Time in meet indus	0.0122*** (0.00)	0.00480*** (0.00)	0.00584*** (0.00)	0.0162*** (0.00)	0.0110*** (0.00)	0.00670*** (0.00)	0.0111*** (0.00)	-0.00215 (0.00)
Founds profit com	0.00227*** (0.00)	0.00178*** (0.00)	0.00188*** (0.00)	0.00185*** (0.00)	0.00125*** (0.00)	0.00135*** (0.00)	0.000699*** (0.00)	0.00187*** (0.00)
Department dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
School dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.280*** (0.090)	0.235*** (0.080)	0.0575 (0.080)	-0.212*** (0.080)	-0.0959 (0.060)	-0.0602 (0.060)	-0.160** (0.070)	0.522* (0.280)
Observations	6,092	6,213	6,175	6,213	6,117	6,091	6,091	1,088
prob>F	0	0	0	0	0	0	0	0
F test	67.8	78.02	59.83	26.72	25.42	23	14.59	9.77
R-squared	0.341	0.37	0.32	0.177	0.173	0.16	0.12	0.45

*** p<0.01, ** p<0.05, * p<0.1; Linear probability OLS models; Standard errors in parentheses

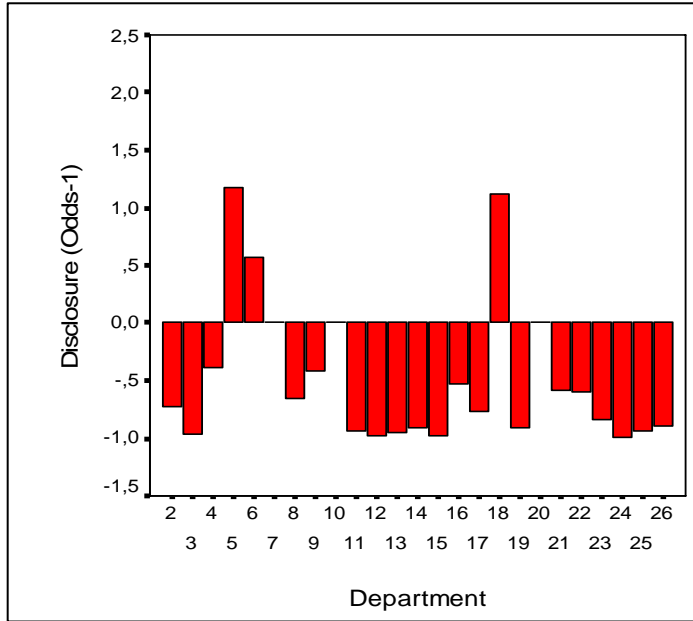


Figure 6: Odds ratios on department dummies for Disclosure (baseline dept: aerospace). In this and the following figures, the reported columns indicate the statistically significant coefficient estimates on a given department dummies, in a model that includes gender, age categories, publication records and research funding. The estimates are odds ratios (subtracted by 1) from a logit model. Th deptment codes are reported at the bottom of Figure 5 above.

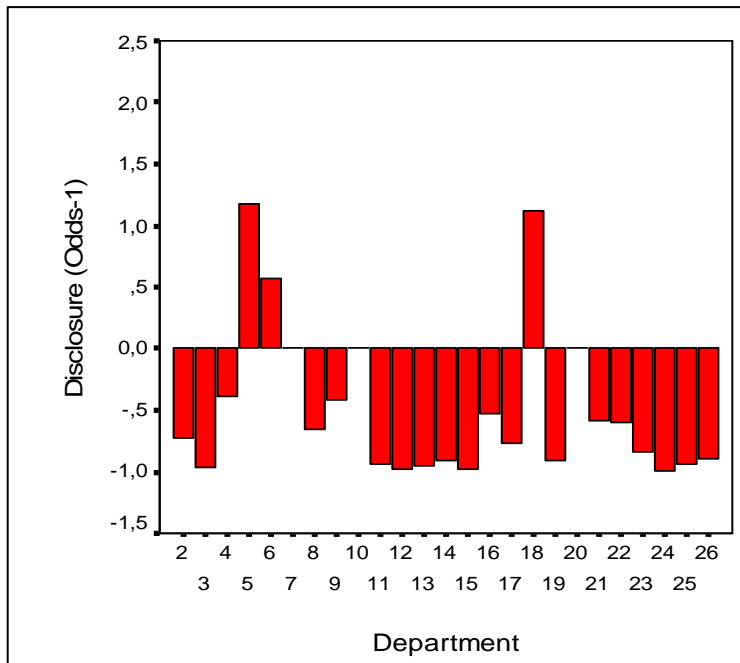


Figure 7: Odds ratios on department dummies for Patent (baseline dept: aerospace)

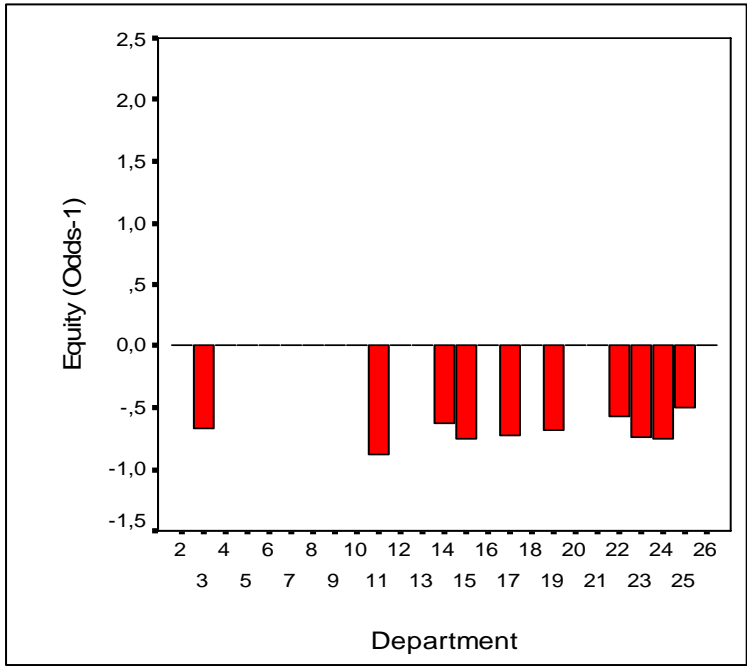


Figure 8: Odds ratios on department dummies for Equity (baseline dept: aerospace)

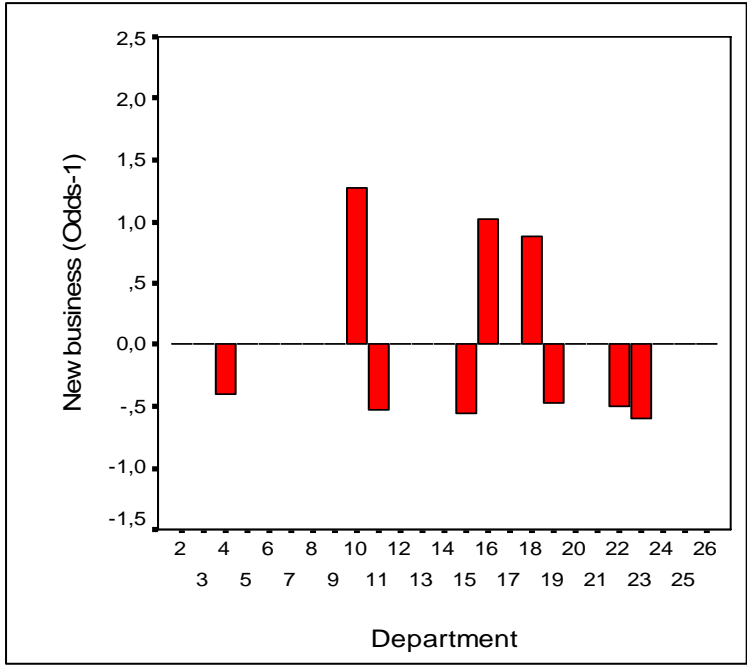


Figure 9: Odds ratios on department dummies for New Business (baseline dept: aerospace)

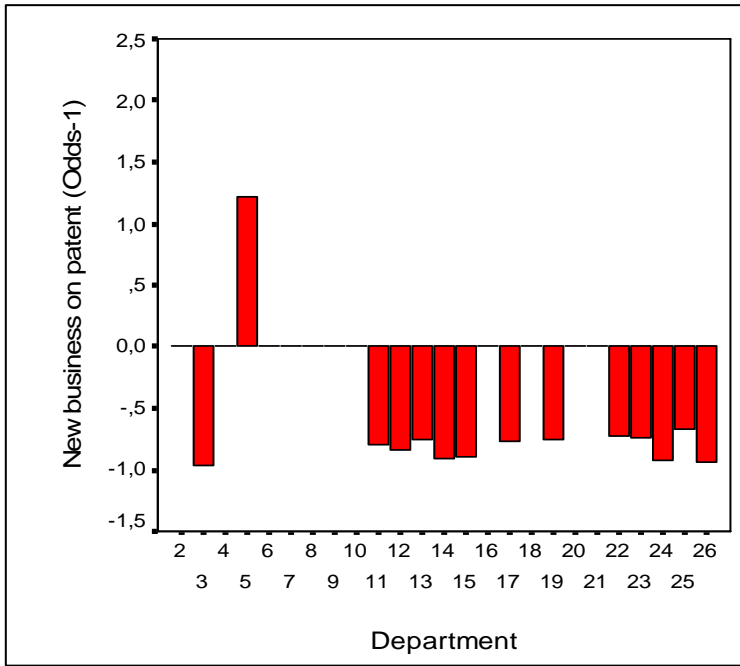


Figure 10: Odds ratios on department dummies for New business on patent (baseline dept: aerospace)

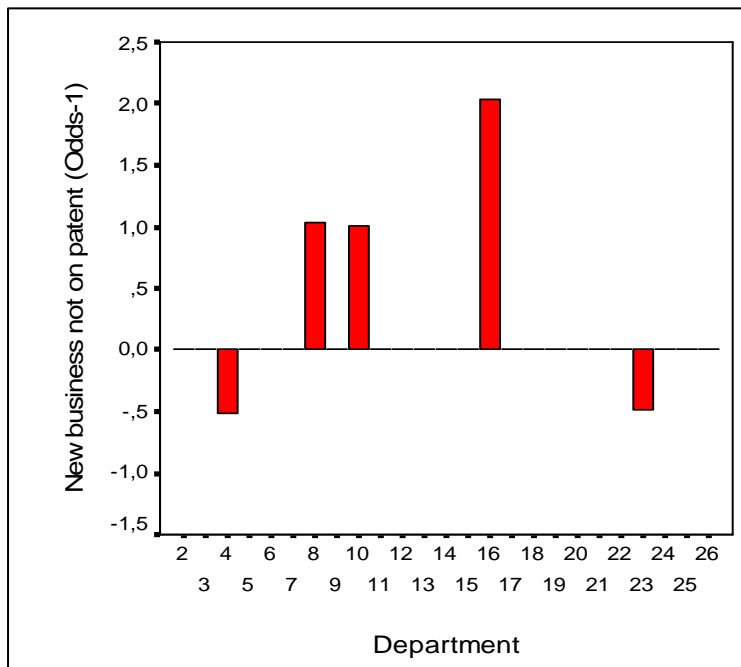


Figure 11: Odds ratios on department dummies for New business not on patent (baseline dept: aerospace)