Entrepreneurship and Human Capital: Evidence of Patenting Activity from the Academic Sector.

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Abstract:

This paper presents empirical evidence of the relationship between faculty entrepreneurial activity—quantified in terms of the propensity of U.S. university faculty to work directly with industry on research activities that lead to patents—and human capital, measured in terms of faculty tenure and age. Patenting reflects a unique dimension of faculty entrepreneurship, namely, collaborative activity that results in joint intellectual property. We find that faculty with tenure are more likely to engage in such activity, thus providing suggestive evidence of an externality associated with permanent employment. We also find that older faculty are more likely to engage with industry, to a point, holding tenure constant. Tenure and age proxy, respectively, what we call the “accumulated advantage” of faculty and their absorptive capacity. Because faculty patenting with industry involved both parties, our findings reflect that such faculty experience and expertise are important to industry to enter into a patenting relationship. Finally, we find that male faculty are more likely to patent with industry than female faculty.

Keywords: entrepreneurship | human capital | patenting | faculty entrepreneurial activity | university faculty | research activities

Article:

Introduction

Since the enactment of the Bayh–Dole Act in 1980, there has been a rapid increase in commercial knowledge transfers from U.S. universities to firms through such mechanisms as licensing agreements, research joint ventures, and university-based startups. For a history of the Bayh–Dole Act, see, for example, Stevens (2004); for an overview of public policy implications related to Bayh–Dole, see Mowery, Nelson, Sampat, and Ziedonis (2004) and Link (2006). Such transfer activities have been welcomed by universities as a potential source of revenue, as a vehicle to build relationships with external stakeholders, and as a means to enhance regional economic growth and development. A concomitant trend has been a burgeoning literature on the economics, managerial, and policy implications of such university technology transfers.

As Link and Siegel (2007) have argued, scholars who assess university technology transfer have examined institutions that have emerged to facilitate entrepreneurial commercialization, such as university technology transfer offices (TTOs), industry-university cooperative research centers, research/science parks, and incubators (Phan, Siegel, & Wright, 2005). However, certain research questions are better addressed by focusing directly on agents involved in technology commercialization, such as academic scientists and engineers (Vanaelst et al., 2006).

A smaller, yet equally important, literature has also emerged that focuses on the individual-level behavior relating to technology transfer mechanisms. Specifically, as reviewed in Link, Siegel, and Bozeman (forthcoming a), several authors have examined the determinants and outcomes of faculty involvement in university technology transfer, such as their propensity to disclose inventions and establish university-based spin-offs.

Conspicuously absent from the institution and agent technology transfer literature is a systematic and broad-based analysis of the entrepreneurial activity of faculty as measured by their propensity to patent (Link & Siegel, 2007). This paper is an initial descriptive attempt to fill that void. The human capital dimensions of faculty are captured by their tenure status and age. As discussed below, drawing on aspects of human capital theory as related to innovative activity, these dimensions are positively related to the propensity of faculty to patent with industry. They are indicators of academic accomplishment and experience, both of which signal to industry research ability that is transferable to intellectual pursuits.

The Individual Contexts of University Technology Transfer

Several studies have focused on individual scientists and entrepreneurs in the context of university technology transfer, but few have examined the influence of human capital on the propensity to patent (Link & Siegel, 2007). We review below aspects of that focused literature, and this review motivates our subsequent hypotheses and empirical analysis. But, because patenting activity at universities is related to university spin-offs (Shane, 2004; Wright, Birley, &

Mosey, 2004), selected key papers that emphasize star scientists or university researchers are also overviewed.

Audretsch (2000) examined the extent to which entrepreneurs at universities are different than other entrepreneurs. He analyzed a dataset on university life scientists in order to estimate the determinants of the probability that they will establish a new biotechnology firm, and he found that university entrepreneurs tend to be older and more scientifically experienced. Audretsch offered no explanation for this finding, although it is consistent with our theory (below) that age approximated the absorptive capacity of faculty.

Whittington and Smith-Doerr (2005) examined gender differences in the patenting productivity of academic scientists. They studied a sample of life science PhDs who had been involved in a university research program that had received a National Institute of General Medical Sciences research service award, and these scientists were matched to the National Bureau of Economic Research Patent Citation Date File. Their analysis suggests that academic females patent less than males but that the commercial value of their patents, measured in terms of citations, is equal to or greater than males.

Wright, Vohora, and Lockett (2004) examine, through case studies of U.K. university spinout formations, the efficacy of joint venture spinout (JVSO) companies. A JVSO is a new venture in which technology is assigned or licensed into a new company that is jointly owned by the university and the industrial partner (p. 307).

> . . . JVSOs may provide a faster, more flexible, less risky and less costly business venturing route to commercializing university intellectual property in comparison to venture backed university start-ups.

In a sense, faculty patenting activity with industry is a form of a joint venture research relationship, and one that may be more efficient than sole academic patenting or sole industry patenting. This is not a point tested empirically in this paper, but rather a topic for future study.

More broadly, Zucker and Darby, and their various collaborators, explored the role of star scientists in the life sciences on the creation and location of new biotechnology firms in the United States and Japan. Zucker, Darby, and Armstrong (2000) assessed the impact of these university scientists on the research productivity of U.S. firms. A star scientist is defined as a researcher who has discovered over 40 genetic sequences, and affiliations with firms are defined through co-authoring between the star scientist and industry scientists. Some of these scientists resigned from the university to establish a new firm or kept their faculty position, but worked very closely with industry scientists. Research productivity is measured using three proxies: (1) number of patents granted, (2) number of products in development, and (3) number of products on the market. They found that ties between star scientists and firm scientists have a positive effect on these three dimensions of research productivity, as well as other aspects of firm performance and rates of entry in the U.S. biotechnology industry (Zucker, Darby, & Armstrong, 1998; Zucker, Darby, & Brewer 1998).

Zucker and Darby (2001) also examined detailed data on the outcomes of collaborations between star university scientists and biotechnology firms in Japan. Similar patterns emerged in the sense that they found that such interactions substantially enhanced the research productivity of Japanese firms, as measured by the rate of firm patenting, product innovation, and market introductions of new products. However, they also reported an absence of geographically localized knowledge spillovers resulting from university technology transfer in Japan, in contrast to the United States, where they found that such effects were strong. The authors attributed this result to the following interesting institutional difference between Japan and the United States in university technology transfer. In the United States, it is common for academic scientists to work with firm scientists at the firm's laboratories; in Japan, firm scientists typically work in the academic scientist's laboratory. Thus, according to the authors, it is not surprising that the local economic development impact of university technology transfer appears to be lower in Japan than in the United States.

The unit of analysis in Bercovitz and Feldman (2004) was also the individual faculty member. They analyzed the propensity of U.S. medical school researchers at Duke University and Johns Hopkins University to file invention disclosures, a potential precursor to technology commercialization. The authors found that three factors influence the decision to disclose inventions: norms at the institutions where the researchers were trained and the disclosure behaviors of their department chairs and peers, respectively. These authors ignored human capital measures and only emphasized institutional effects.

Roberts and Malone (1996) also ignored human capital effects. Based on an in-depth case study of Stanford University in the early 1990s, they conjectured that much of the entrepreneurial activity that was stimulated through technology transfer was a direct result of university policies. They noted that during this period, Stanford refused to grant exclusive licenses to inventor-founders. Relatedly, DiGregorio and Shane (2003) directly assessed the determinants of startup formation using the Association of University Technology Managers' data. They concluded that the two key determinants of start-ups are faculty quality and the ability of the university and inventor(s) to assume equity in a start-up in lieu of licensing royalty fees.

Louis, Blumenthal, Gluck, and Stoto (1989) analyzed the propensity of life-science faculty to engage in various aspects of technology transfer, including commercialization. Their statistical sample consisted of life scientists at the 50 U.S. research universities that received the most funding from the U.S. National Institutes of Health. The authors found that the most important determinant of involvement in technology commercialization was local group norms; they reported that university policies and various types of organizational structures had little effect on this activity.

In a similar vein, Nicolaou and Birley (2003) investigated the consequences of considering the social networks of academic entrepreneurs as a determinant of spinout types. Similar to Mustar et al. (2006), they adopted a structural contingency view of spinout types and sought to describe the various forms with reference to the social network structure of the academic entrepreneurs involved in the spinouts. Academics with strong ties to the external environment that are non-redundant were found to be more likely to engage in spinouts.

To the extent that the successful commercialization of university-based technology depends on the individual incentives, risk taking propensities, and skill sets of academic entrepreneurs, the extant research seems to suggest that paying attention to the individual level of analysis matters in building more complete understanding of technology transfer effectiveness.

Theory and Hypotheses

The theoretical motivation for our hypotheses comes from several veins of research in the extant literature on entrepreneurship. First, we motivate patenting activity as an entrepreneurial activity by drawing on the writings of Schumpeter.1

University faculty are engaged in basic research and basic research can lead to inventions that, according to Bayh–Dole, are to be disclosed through their university's TTO. However, inventions can go out the back door and skirt the TTO process, as documented by Markman, Gianodis, and Phan (2006) and by Link et al. (forthcoming a), or they can be patented with an industry partner.

Schumpeter described entrepreneurial innovation in several ways. Initially he spelled out the kinds of new combinations that underlie economic development. They encompass the following: (1) creation of a new good or new quality of good; (2) creation of a new method of production; (3) the opening of a new market; (4) the capture of a new source of supply; and (5) a new organization of industry (e.g., creation or destruction of a monopoly). Schumpeter (1939) also envisioned such entrepreneurial innovation in terms of a production function. The production function, he said (p. 62):

> . . . describes the way in which quantity of product varies if quantities of factors vary. If, instead of quantities of factors, we vary the form of the function, we have an innovation.

Mere cost-reducing adaptations of knowledge lead only to new supply schedules of existing goods; however, this kind of innovation must involve a new commodity, or one of higher quality. Faculty-with-industry scientists patenting is, in a sense, a variation of the innovation production function and one that illustrates a response to the perception of an entrepreneurial opportunity.

Our analysis focuses on three human capital variables that we hypothesize explain faculty involvement with industry in patenting activity. These variables are the tenure status of the faculty member, his/her age, and his/her gender.

Tenure is a dimension of institutional human capital. It proxies what we call the "accumulated advantage" of faculty, meaning that tenured faculty are at the top research universities because of their demonstrated research ability. Faculty in general are involved in basic research, and those who have been awarded tenure, especially at major research universities, may be viewed by industry as those who could enhance the human capital of their research team. As recently expressed by the National Science Board (forthcoming):2

> . . . a company that is involved in basic research could boost [its internal] human capital by attracting academically motivated and experienced scientists and engineers to strengthen its [internal] scientific and technological knowledge base.

Thus, it follows:

> Hypothesis 1: Tenured faculty are more likely to patent with industry than non-tenured faculty.

Following Cohen and Levinthal (1989), age is another dimension of human capital that proxies a faculty member's absorptive capacity, and the greater that absorptive capacity the more valuable a faculty member may be to industry in research processes.

Relatedly, Hall, Link, and Scott (2003, p. 491) concluded from their analysis of university-with-industry joint research activities that university faculty:

> . . . are included (invited by industry) in those research projects [where they] could provide research insight that is anticipatory of future research problems and [where they could] be an ombudsman anticipating and communicating to all parties the complexity of the research undertaken. Thus, one finds [university faculty] purposively involved in projects that are characterized as problematic with regard to the use of basic knowledge.

Research insight, we conjecture, comes with academic experience as proxied by age. Of course, tenure and age are not necessarily independent characteristics of faculty. Many faculty gain an accumulated advantage in research with age, absent tenure, and research insights may be gained over time thus leading to tenure. As with any dimension of human capital, there are diminishing returns. Thus, the effect of age on the propensity to patent with industry will eventually decrease. And, to the extent that age approximates university experience, the same arguments will hold. This argument motivates Hypotheses 2 and 3. However, it is an empirical issue as to the age or experience level of faculty at which diminishing returns set in.

Thus:

> Hypothesis 2: Older faculty are more likely to patent with industry than younger faculty, to a point and then the impact of age will decrease.
>
> Hypothesis 3: More experienced faculty are more likely to patent with industry than less experienced faculty, to a point and then the impact of experience will decrease.

Finally, the impact of gender on the propensity to patent is primarily an empirical issue. The extant literature on gender is in its infancy. Motivating Hypothesis 4 are the sole empirical findings of Whittington and Smith-Doerr (2005), as reviewed above. Because female academics are less involved *per se* in the patenting process than male faculty, they are also less likely to partner with industry in that entrepreneurial activity.

Thus, with this limitation in mind, we offer the following:

Hypothesis 4: Male faculty are more likely to patent with industry than female faculty.

Research Methodology

Our empirical model of faculty patenting, *Patent*, is:

Patent = f(Tenure, Age, Gender, X)

Where vector X represents other demographic control characteristics of faculty such as race, marital status, field of research, and academic institution. We offer no hypotheses about the effect of these control characteristics on the propensity of faculty to patent.

Our data on faculty involvement in patenting are derived from the National Science Foundation/Department of Energy Survey of Academic Researchers constructed under the sponsorship of these agencies within the Research Value Mapping Program Survey of Academic Researchers. Survey data were collected from a sample of university scientists and engineers with a PhD at the 150 Carnegie Extensive Doctoral/Research Universities during the time period spring 2004 to spring 2005. The sample of researchers selected to receive the survey was not random but rather proportional to the number of academic researchers in the various fields of science and engineering, and it was balanced between randomly selected men and women.

The target sample was 200 men and 200 women from each of the 12 National Science Foundation science and technology disciplines: Biology, Computer Science, Mathematics, Physics, Earth and Atmospheric Science, Chemistry, Agriculture, Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, and Materials Engineering. Sampling proportions by gender and field are taken into account in the weighted regressions discussed below.

To the best of our knowledge, this study represents the first systematic collection of such information from a large cross section of U.S. university scientists and engineers.

Our focus from this dataset is on the propensity of faculty to patent based on faculty responses to the statement: During the past twelve months, I have worked directly with industry personnel in work that resulted in a patent or copyright. An affirmative response to this statement reflects a unique dimension of faculty entrepreneurship, namely collaborative activity that results in joint intellectual property, and it defines the dichotomous nature of our dependent variable, Patent. While there are clearly other dimensions of academic entrepreneurship, as discussed by Shane (2004) and Link and Siegel (forthcoming a), patenting is the only dimension included in our dataset.

Analysis and Results

We constructed sampling weights so that the analyzed sample is representative of the population of PhD academic scientists and engineers. We also limited the sample to professors aged 65 and younger. Thus, all of the analyzes presented and discussed below are based on weighted data; our conclusions therefore relate to the population of academic scientists and engineers aged 65 and younger at the 150 top research universities in the United States.3

Based on weighted data, 6.3% of our sample of 1,335 faculty engage in patent activity. Table 1 shows that faculty who patent are more likely to be tenured and more likely to be full professors. They are more likely to be male, white or Asian, and much more likely to be a U.S. citizen. The predominant disciplines for patenting activity are electrical and mechanical engineering. Of the 78 faculty engaged with industry in patenting activity, 92% were male, 82% were white, and 85% were tenured.

Table 1. Descriptive Statistics from Weighted Sample†

Variable	Complete sample	Patents	No patents
Patent	.063	1.000	.000
Tenure	.747	.848	.740
Assistant	.232	.158	.237
Associate	.260	.172	.265
Full	.509	.670	.498
Male	.862	.921	.858
Age	48.6 (9.2)	49.4 (7.4)	48.6 (9.3)
PhD experience	19.5 (9.8)	19.8 (8.4)	19.4 (9.8)
White	.797	.820	.795
Asian	.140	.169	.138
Black or other	.068	.011	.072
Citizen	.858	.982	.849
Married	.901	.926	.899
Number of children	1.072 (1.261)	1.181 (1.119)	1.065 (1.269)
Agriculture	.039	.050	.038
Biology	.142	.042	.149
Computer Science	.104	.120	.103
Physics	.137	.080	.141
Earth Science	.080	.005	.085

Variable	Complete sample	Patents	No patents
Chemistry	.132	.097	.135
Chemical Engineering	.086	.102	.042
Civil Engineering	.107	.064	.087
Electrical Engineering	.096	.226	.099
Mechanical Engineering	.031	.143	.092
Material Engineering	.063	.071	.029
Observations	1,335	78	1,257

† Mean (Standard deviation)

Note: Data are limited to professors aged 65 and younger from the Survey of Academic Researchers and are weighted to represent the academic scientists and engineers at the 150 top research universities in the United States.

Table 2 reports the correlation coefficients among a selected group of variables. Having tenure, being a full professor, being white, a U.S. citizen, older, or having more experience are all associated with more patent activity. Being an associate professor has a negative correlation with patent activity. In our later regression results, we will show that the effects of tenure and promotion are quite different. Tenure is positively associated with patent activity, while being promoted, especially to just associate professor, is negatively related to patent activity, once we account for tenure.

Table 2. Correlation Matrix of Weighted Variables (n = 1,335)

	Patent	Tenure	Associate professor	Full professor	Male	Age	PhD experience	White	Citizen
Patent	1.000								
Tenure	.056	1.000							
Associate	−.049	.302	1.000						

	Patent	Tenure	Associate professor	Full professor	Male	Age	PhD experience	White	Citizen
Full	.086	.549	−.545	1.000					
Male	.056	.157	−.055	.197	1.000				
Age	.040	.561	−.078	.604	.271	1.000			
PhD experience	.040	.597	−.120	.667	.311	.914	1.000		
White	.023	.111	.006	.091	−.088	.133	.139	1.000	
Citizen	.057	.258	.057	.180	.025	.261	.248	0.213	1.000

Note: Data are limited to professors aged 65 and younger from the Survey of Academic Researchers and are weighted to represent the academic scientists and engineers at the 150 top research universities in the United States.

Table 3 presents propensities for patent activity by rank and tenure. The first item to note is that we have 14 tenured assistant professors, 32 untenured associate professors, and 10 untenured full professors; these cases will allow us to separate the effects of rank and tenure. Table 3 previews our later regression results by showing that at all ranks, tenured professors are much more likely to patent than untenured professors (8.1 to 4.1% for assistant professors, 4.4 to 1.5% for associate professors, and 8.4 to 0.0% for full professors).

Table 3. Patent Activity by Rank and Tenure†

Rank	Tenure	No tenure
Assistant professor	.081 (.076) [n = 14]	.041 (.010) [n = 370]
Associate professor	.044 (.011) [n = 343]	0.015 (0.022) [n = 32]
Full professor	.084 (.011) [n = 566]	.000 (—) [n = 10]

† Mean (Standard error)

Note: Data are limited to professors aged 65 and younger from the Survey of Academic Researchers and are weighted to represent the academic scientists and engineers at the 150 top research universities in the United States.

Owing to the dichotomous nature of the patent variable, Patent, hierarchical variations of equation 1 are estimated using probit analysis, and the estimated results are in Table 4. Heteroskedasticity and multicollinearity are inherent in regressions using cross sectional data. The standard errors in Table 4 are robust, thus the first potential econometric problem has been account for.

Table 4. Probit Estimates of the Determinants of Patent Activity†

Explanatory variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5) Males**	**(6) Females**
Tenure	.004 (.021)	.031 (.021)	.035 (.020)	.034 (.014)*	.052 (.019)**	−.016 (.036)
Associate	—	−.046 (.021)*	−.041 (.022)	−.046 (.016)**	−.066 (.023)**	.009 (.040)
Full	—	−.017 (.033)	−.002 (.034)	−.031 (.031)	−.064 (.051)	.055 (.066)
Male	.026 (.011)*	.024 (.011)*	.025 (.011)*	.015 (.010)	—	—
Asian	.014 (.028)	.019 (.029)	.016 (.027)	−.002 (.017)	−.005 (.021)	.004 (.021)
Black or other	−.041 (.013)**	−.041 (.012)**	−.040 (.012)**	−.033 (.008)**	−.038 (.010)**	−.018 (.013)
Citizen	.055 (.011)**	.053 (.010)**	.053 (.010)**	.041 (.008)**	.056 (.012)**	−.009 (.017)
Married	.011 (.025)	.010 (.024)	.010 (.025)	.010 (.019)	.009 (.028)	.010 (.011)
Number of children	−.003 (.006)	−.003 (.006)	−.003 (.006)	−.003 (.005)	−.003 (.006)	−.011 (.005)
Age	.022 (.011)*	.020 (.011)	.029 (.014)*	.027 (.011)*	.041 (.017)*	−.006 (.009)
$Age^2/100$	−.022 (.011)*	−.022 (.011)*	−.028 (.015)	−.027 (.012)*	−.040 (.018)*	.006 (.009)
PhD experience	—	—	−.008 (.006)	−.005 (.005)	−.010 (.007)	.009 (.004)*

Explanatory variable	(1)	(2)	(3)	(4)	(5) Males	(6) Females
PhD experience^2/100	—	—	.013 (.013)	.009 (.010)	.018 (.014)	−.022 (.010)*
Discipline indicators	No	No	No	Yes	Yes	Yes
Pseudo R^2	.0550	.0683	.0739	.1463	.1450	.1500
Observations	1,335	1,335	1,335	1,335	538	605

* = significant at 5% level;

** = significant at 1% level

† Derivative (Standard error)

Notes: Data are limited to professors aged 65 and younger from the Survey of Academic Researchers and are weighted to represent the academic scientists and engineers at the 150 top research universities in the United States. Derivatives (or discrete changes for continuous variables) are evaluated at the mean. Standard errors are heteroskedasticity-robust.

With regard to multicollinearity, the estimated coefficients remain unbiased and the standard errors are higher, thus making statistical tests more difficult. We did calculate variance inflation factors (VIFs) for all variables in all specifications and multicollinearity did not appear to be an issue.4 For example, in specification (3) discussed below, upon which much of the discussion of the results is based, the VIF on Tenure is 5.62, which would suggest that our standard error is the square root of 5.62 or 2.37 times larger than it would be if not for the multicollinearity. That would suggest that if we regressed Patent onto Tenure alone, our standard error would be 2.37 times smaller. But, the standard error actually increases from 0.0140 to 0.0184 in a specification with just Tenure. The reason for this is that when the additional controls are added, the numerator of the standard error formula also shrinks and it shrinks faster than the denominator does. So we get an “inflated” standard error that is smaller than our non-inflated standard error.

Specification (1) in Table 4 shows that without conditioning on academic rank, Tenure appears to have very little effect on patent activity. However, once academic rank controls are included in specification (2), tenure increases patent activity by 3.1 percentage points—a large effect given that only 6.3% of the sample engages in patent activity. However, this effect is not statistically significant in specification (2), but it will become statistically significant as more controls are included. Holding tenure constant, being promoted from assistant to associate professor decreases patent activity by a statistically significant 4.6 percentage points. Holding tenure constant, full professors are also less likely to patent than assistants, although this effect is never statistically significant.5

We also find that males are 2.4 percentage points more likely to patent, and blacks and those of other races are 4.1 percentage points less likely to patent. Professors patent more with age until their late 40s, when patent activity begins to decline. Finally, U.S. citizens are 5.3 percentage points more likely to partner with industry and to patent. Although the data do not permit a more detailed analysis of the citizenship effect, it could be that U.S. firms are more comfortable in filing a U.S. patent with a U.S. citizen, or that non-U.S. citizens have a lesser incentive to patent with U.S. firms.

In specification (3), we include controls for years of experience since receiving a PhD (and its square), and tenure and rank remain nonsignificant.6 Specification (4) includes binary variables for academic fields7 and this improves the fit of the model so that the tenure effect is now statistically significant, which supports hypothesis 1. In this specification, the effects of tenure would suggest that the elimination of tenure (with promotion remaining intact) would reduce faculty patent activity by 55%. We arrived at this value by setting Tenure equal to zero for all faculty in the sample and then predicting the probability of patenting for each faculty member. Summing these probabilities over the whole sample, we find that patent activity is reduced by 55% 8 While more analysis needs to done to establish these effects as causal, the data certainly hints at a very strong positive effect of tenure on the propensity to patent. Marital status and number of children never have a statistically significant impact.

Faculty age has a positive effect in specifications (1) through (4) and is generally statistically significant, and nonlinearly related to patenting although the nonlinear effect is which supports hypothesis 2. The age effect is stronger among males. There is almost no impact on the Tenure or Age coefficients from adding controls for years of PhD experience in specification (3). Specifications (5) and (6) split the sample by males and females,9 and hypothesis 3 is confirmed only with respect to females; the propensity of females to patent increases with experience to a point.

Specifications (1) through (4) show that males are more likely to patent with industry than females, which supports hypothesis 4, although the estimated coefficient is not statistically significant in specification (4). The findings in specifications (5) and (6), when the sample is split by gender, suggest that the tenure and rank effects are almost entirely due to males.

Tenure is negatively associated with patent activity for females. Included in other specifications (not shown) are university effects. The sample size is reduced in these specifications by 28 universities or by 336 observations because none of the faculty at these universities was involved in patenting activity. In the smaller sample, the tenure and rank effects are largely unchanged.10

Discussion and Conclusion

Each of our hypotheses was supported by our empirical analyzes. Tenured, older and more experienced male faculty are more likely to patent with industry. These findings contribute to the literature by being one of the first to emphasize empirically at the micro level the role of human capital in the faculty entrepreneurial activity of patenting. As such, our findings may provide some guidance and insight to university administrators on some of the more subtle implications of tenure and aging faculty.

Tenure, meaning in the broadest sense—lifelong employment at the university—is granted to faculty but not without cost. As Link, Swann, and Bozeman (forthcoming b) show, faculty with tenure devote fewer hours to teaching and to research, two categories of activities that are fundamental to a university, especially research to a research university. However, our results show that tenure does have other effects, namely, patenting with industry.

As universities, especially state universities, are being forced for fiscal reasons to rely less and less on state allocations, licensing revenues are and will continue to be a more important category of revenue. Thus, it is in the long-run financial interest of universities to encourage faculty to patent and to license through the university's TTO, and those with tenure are doing just that but not necessarily through the university TTO. But, based on our findings that being promoted to associate professor decreases the propensity to patent, it could be the case that conferring lifelong employment at any rank is a key to patentable entrepreneurial activity.

Additional research on the managerial and economic impacts of tenure is certainly needed in the future. Such questions that might be investigated are whether the quality of faculty research and teaching changes with the award of lifetime employment. And, to keep to the broad theme of this paper, do faculty—once receiving tenure—begin to seek to supplement their salaries either through patenting activities or consulting activities. Should future research find that quality does decline and/or that extramural financial endeavors do increase with the confirmation of tenure, then university administrators have a host of management issues to deal with, especially if this occurs at research universities with a mission to expand the scope of basic research.

Additional research is also needed on the impact of gender on patenting activity. While we did posit a hypothesis about gender, it should be emphasized that the hypothesis followed from a literature that is still in its infancy. Generalizations from our findings about gender effect on patenting, much less generalizations about gender effects on entrepreneurial activity in general, should be made cautiously.

It is important to offer several qualifications about our analysis. First, our data do not quantify the quality of the patented innovations, which is related to whether it can be licensed; patents are not homogeneous. Second, our data do not account for whether the university TTO was involved in the research/patenting process, as opposed to the innovation going out the back door. Third, our data are not longitudinal. Future research on the propensity of academics to partner and to patent with industry should examine the lifecycle of such a relationship. Fourth, while our analysis did control for field and university effects, no specific institutional variables are available such as the efficiency of the university TTO or the university or departmental incentive structure as related to patenting activity. Thus, we could not control for the size or expertise or the TTO. As Lockett and Wright (2005) have shown using U.K. university data, spin-offs are more likely to occur when the TTO staff is available and experienced. With regard to our findings, it could be that faculty choose to patent with industry in the absence of these institutional conditions. And fifth, an important dimension of patenting that we could not examine is the interrelationship between patenting and academic research. A relevant question that needs to be examined is what happens to the quantity and quality of a faculty members' academic research once he/she begins to patent with industry? Another relevant question—and this question follows from Wright et al.'s (2004) analysis of joint venture spin-out companies and from Hall et al.'s (2003) of university faculty as partners in research joint ventures—are faculty patents with industry more valuable, in a citation or licensing sense, than patents from academics alone or than patents from industry alone owing to the value added from both parties? Caveats aside, our analysis is a first step to a micro-level understanding of this aspect of faculty behavior and one that will hopefully generate future research on this topic.

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Footnotes

1 For a more complete discussion of the Schumpeterian view of innovation and entrepreneurial activity, see Hébert and Link (2006a, 2006b) and Shane (2003).

2 This quotation is taken from p. 23 of the April 4, 2007 draft of Chapter 4 of 2008 Science and Engineering Indicators.

3 Detailed information on the sampling weights is available from the authors on request. Math professors (n = 91) were deleted, because none were involved with industry in patent activity; thus, that variable predicted perfectly in the later probit regressions.

4 These results are available from the authors on request.

5 As one referee noted, the negative effect of promotion may indicate that promotion is based on basic research output, such as journal publications, and faculty who excel in that dimension may be less likely to enter into the more applied areas, which lead to patents.

6 Alternatively, we defined experience as year with tenure. When so measured, the estimated coefficient was not significant. These results are available from the authors on request.

7 See Table 1 for the included academic fields.

8 The 95% confidence interval for this effect ranges from a 5% to 76% reduction in patent activity, based on calculations assuming a tenure effect equal to the estimated Tenure coefficient plus or minus 1.96 times its standard error.

9 When the sample is split by gender, the sample size is smaller because some disciplines perfectly predict patent activity.

10 These results are available from the authors on request. The estimated coefficients for UCLA and the University of Arizona were positive and significant; the estimated coefficients were negative and significant for Virginia Tech, the University of Texas, Iowa State, and Clemson.