Does Scientific Innovation Lead to Entrepreneurship? A Comparison of Academic and Industry Sectors

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Abstract:

This paper contributes to the literature on innovation and entrepreneurship by providing sector-specific definitions of entrepreneurial activity and linking these measures to innovation. Using three waves of the Survey of Doctorate Recipients, the analysis begins by investigating the demographic, employer, and productivity characteristics associated with publications and patents in both sectors by US Ph.D. scientists. Descriptive regressions show the factors associated with patenting by US scientists are very similar across the academic and industry sectors. I also find that innovation, measured by patents granted and patents commercialized, is positively associated with academic entrepreneurship measured by having a second job. After controlling for individual fixed-effects, these relationships change. The commercialization of patents is associated with academic entrepreneurship measured by having a second job, whereas patents granted have no significant effect. Patents granted also have a positive effect on employment in a small, entrepreneurial firm but are not associated with incorporated self-employment or new business employment in the industry sector. Taken together, these results indicate that innovation does lead to entrepreneurship in both the academic and industry sectors with the effects for academics being more pronounced.

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"the independent innovator and the independent entrepreneur have tended to account for most of the true, fundamentally novel innovations. . . It is a plausible observation, then, that perhaps most of the revolutionary new ideas of the past two centuries have been, and are likely to continue to be, provided by these independent innovators who, essentially, operate small business enterprises."

William J. Baumol (2004 p.5)

Innovation, in the form of technological change, has been credited with increased productivity and economic growth (Oliner and Sichel 2000; Jorgenson and Stiroh 2000). Others argue that entrepreneurship is a form of human capital that makes its own unique contribution to growth (Audretsch and Keilbach 2004, 2005; Audretsch and Thurik 2001; Schramm 2004). Baumol combines the two activities, stating: "It is the entrepreneur's function to locate new ideas and to put them into effect." (Baumol 1968). This paper uses the Survey of Doctorate Recipients to examine the linkages between innovation and entrepreneurship among US Ph.D. scientists in the academic and industry sectors. In accordance with Baumol's predictions, this paper finds that innovation leads to entrepreneurial activity in both academia and industry, but the process differs across the sectors.

Innovation is a relatively straightforward concept to define and measure whereas entrepreneurship presents more of a moving target. The *New Oxford American Dictionary* defines innovation as "the action or process of innovating--a new method, idea, or product." In the analysis presented below, innovation is measured by publications, patent applications, and patents granted. The *New Oxford American Dictionary* defines an entrepreneur as "a person who organizes and operates a business or businesses, taking on greater than normal financial risks in order to do so;" this definition does not mention innovation.

The economics literature has not settled on a consistent definition of entrepreneurship. Several researchers, mostly labor economists, define entrepreneurship as self employment (Evans and Leighton 1989; Blanchflower and Oswald 1998; Hamilton 2000). Lazear (2005) refines this definition to be incorporated self-employment. Baumol (1968, 1990, 2004) links innovation with entrepreneurship, using the two terms interchangeably.

In keeping with the dictionary, Reynolds, Carter, Gartner and Greene (2004) using the Panel Survey of Entrepreneurial Dynamics (PSED), define an entrepreneur as a person engaged in starting a business as does Audretsch and several of his coauthors. However, the employment status of the person starting the business is unclear. An entrepreneur can potentially be working two jobs—one to pay the bills and the other the start of an independent venture. This suggests that measuring entrepreneurship as self-employment may be too narrow a definition. Indeed, Leonard (2008) shows that the PSED definition and the self-employment definition of entrepreneurship lead to significantly different estimates.

The burgeoning literature on academic entrepreneurship most often defines entrepreneurial activity as patent applications and patents granted (see for example, Stephan, Gurmu, Sumell, and Black 2005; Azoulay, Ding, and Stuart 2004, 2005; Fabrizio and DiMinin 2005; Murray and Stern 2005. One notable exception is Toole and Czarnitzki 2005). Others have examined the spillovers between academic science, innovation, and entrepreneurship. Chukumba and Jensen (2005) develop a model that predicts that university inventions are more likely to be commercialized in entrepreneurial start-ups than in established companies. Using data from University

Technology managers they confirm the predictions of the model. Branstetter and Ogura (2005) find that the bioscience industry is more likely to cite academic patents and papers in the 1990s. Zucker, Darby, and their collaborators [Zucker, Darby, et. al.] take a more nuanced approach and examine the involvement of star academic scientists in firm formation. They posit that start scientists are important for technology transfer and firm success (Zucker, Darby, and Brewer 1998; Zucker, Darby, and Armstrong 1998, 2002; Zucker and Darby 2006).

Clearly, defining academic entrepreneurship as patent applications or patents granted is problematic for several reasons. First, the patent application is the initial step in a long process of introducing innovations to the marketplace through commercialization. Second, the 1980 Bayh-Dole Act changed the incentives for universities to patent scientific discoveries. Thus, it may be the institution instead of the scientist who initializes the patent process. Third, not all patent applications are granted, and once granted, not all patents are commercialized. Given the hurdles researchers face between the patent application and profitable commercial venture, I argue that patent applications and grants are more appropriately measures of innovation. Instead, the commercialization of a patent is most closely associated with an actual business venture, and I will examine this empirically in the paper.

Even using commercialization as a measure of academic entrepreneurship presents its own problems. Commercialization may take the form of licensing where the researcher signs over the rights to an unrelated firm. Thus, the researcher is not an entrepreneur per se. Alternatively, if the researcher is actively involved in the commercialization process, he or she may be working as a consultant to the venture that commercializes the discovery or starting a business. Thus, this study uses an indicator of whether an individual has a second job as a measure of academic entrepreneurship. This approach is related to that taken by Zucker, Darby et. al. who examine the success of firms associated with star academic researchers.

As the above discussion indicates, entrepreneurship, as defined in the literature takes on different meanings in different contexts. In addition, much of the literature on innovation has focused on the academy, despite the fact that Morgan, Kruytbosch, and Kannankutty (2001) show that patenting and commercialization rates among scientists are much higher in industry than the academic sector.

This paper contributes to the literature on innovation and entrepreneurship by providing sector-specific definitions of entrepreneurial activity and linking these measures to innovation. Entrepreneurship can take many forms in the industry sector ranging from nascent entrepreneurs who have second jobs, to the person employed in a new business, to the incorporated self-employed. Academics, by definition, are not self-employed, but do engage in the entrepreneurial activities of second jobs which may or may not be related to the commercialization of patents.

This study uses three waves of the Survey of Doctorate Recipients to explore the linkages between innovation and entrepreneurship among US Ph.D. scientists in the academic and industry sectors. The analysis begins by investigating factors associated with patenting in the academic and industry sectors. I examine the demographic, employer, and productivity characteristics associated with publications and patents in both sectors. In part, I evaluate Baumol's hypothesis that a substantial number of inventions take place in small firms. Zucker, Darby et. al. argue that academic "stars" in terms of publications are closely related to startups, and I investigate this association by estimating the effect of publications and patents on having a second job as an academic. These associations will indicate whether innovation is correlated with entrepreneurship.

The analysis continues with an examination of the causal relationship between innovation and entrepreneurship. Using the panel data to control for individual fixed effects, I examine whether patent applications, patent grants, and patent commercialization are associated with self-employment and other measures of entrepreneurial activity in the industry sector. In the academic sector, I examine whether patent applications, patent grants, and patent commercialization are associated with holding a second job. Finally, I evaluate whether academics with patents are more likely to leave tenure-track academia altogether in order to earn higher returns on their innovations.

This study shows that the factors associated with patenting by US scientists are very similar across the academic and industry sectors. I also find that innovation, measured by patents granted and patents commercialized, are positively associated with academic entrepreneurship measured by having a second job. Similarly, patents commercialized are positively correlated with incorporated self-employment and patents granted are positively associated with employment in a new business in the industry sector. Patents granted are positively associated with leaving tenure track academia, however, publications have a negative effect on leaving the tenure track.

After controlling for unobserved, individual heterogeneity, these relationships change. The commercialization of patents has a positive causal effect on academic entrepreneurship measured by having a second job, whereas patents granted have no significant effect. Patents granted also have a positive effect on employment in a small, entrepreneurial firm but have no causal effect on incorporated self-employment or new business employment in the industry sector. Patents commercialized have a weak, positive effect on leaving academia. Taken together, these results indicate that innovation does lead to entrepreneurship in both the academia and industry, however the relationship differs by sector.

The paper proceeds as follows: Section two describes the data, section three details the estimation methods, section four discusses the empirical results and section five concludes.

II. Data and Methods

This study uses data from the 1995, 2001, and 2003 waves of the Survey of Doctorate Recipients (SDR). The SDR is a biennial, longitudinal survey of doctorate recipients from U.S. institutions conducted by the National Science Foundation. The SDR collects detailed information on U.S. science and social science doctorate recipients including demographic characteristics, educational background, employer characteristics, academic rank, government support, primary work activity, and salary.

There are several advantages to using the SDR to examine the relationship between innovation and entrepreneurship. First, most studies of innovation have very limited information on the demographic characteristics, education, and employment background of the individual scientist. The SDR contains very detailed information on these characteristics and follows individuals over time. Second, the SDR contains information on the patenting process from start to commercialization, whereas a number of other studies rely on patents granted or case studies of the commercialization process.

Third, the SDR is a representative sample of all scientists trained in the US. Thus, results from this study are not limited to a subset of scientists in one particular field.

I limit my analysis to individuals in computer science and mathematics, physics, chemistry, life sciences, and engineering because these fields are most likely to generate patentable research. The data are divided into two sectors, those working full-time with non-missing information in four-year academic institutions and those working full-time with non-missing information in the industry sector. Respondents working in the government sector are dropped from the analysis. Individuals may appear in all three waves of the SDR in my sample.

I create two samples from these data. First, I combine data from all years to investigate the correlations between innovation and entrepreneurship. This pooled data set will contain multiple observations for the same individual. Next, I create a longitudinal data set for individuals who appear more than once in the survey. The longitudinal data will be used to examine the causal relationship between innovation and entrepreneurship.

In the 1995, 2001, and 2003 SDR, the survey asks respondents whether they have been named as an inventor on a patent application, the number of patent applications, the number of patents granted, and the number of granted patents commercialized in the previous five years. In addition the surveys ask the number of papers presented at conferences and papers accepted for publication in refereed journals in the previous five years. Publications, presentations, patent applications, patents granted, and patents commercialized will be used to measure innovation in both samples.

Zucker, Darby et. al. show that academic "stars" in terms of publications are closely associated with new firms in the biotechnology and nanotechnology industries (Zucker, Darby, and Brewer 1998; Zucker, Darby, and Armstrong 1998, 2002; Darby and Zucker 2006; Zucker and Darby 2006c). They are able to identify the names of the scientists, the number of publications, coauthors on the publications (and their affiliations) and the firms they are associated with. Their 'Star' publishers are identified from the *ISIHighlyCited*® (http://www.ISIHighlyCited.com) component of the ISI Web of Science®. The SDR does not allow me to identify individuals or firms in the data. Instead, I create a proxy for star publishers as anyone who publishes in the top decile of all publishing in the SDR in the previous five years.[1] In order to investigate whether industry entrepreneurs have academic links, I create two variables using the full panel of the SDR. I begin by identifying all individuals who ever held a tenure track job over the 1973 – 2003 waves of the SDR. Next, using these same waves, I identify those who leave tenure track academia permanently. Measures of having held a tenure track job are included in estimates of nonacademic entrepreneurship.

In addition, the SDR asks detailed questions about the employer sector and size. The SDR contains information on academic institution characteristics. For those working in the non-academic sector, I can identify individuals who are self-employed and whether their business is incorporated. In the 1995 and 2001 surveys, I can also identify whether individuals have a second job, and the relationship of that second job to their doctorate field. The SDR asks employer size and whether the employer was a new business created

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[1] The 90th percentile of publications in the three waves of the SDR was 15 publications in the previous five years. This definition likely defines star publishers more-broadly that in Zucker, Darby, et. al.

within the past five years.[2] Finally, several researchers have noted that universities create positive externalities in the form of geographically local knowledge spillovers (Jaffe 1989; Jaffe, Trajtenberg and Henderson 1993; Zucker, Darby, and Armstrong 1998). I control for this possibility by including state fixed effects.

Typically, researchers have used self-employment status as a measure of entrepreneurship in the non-academic sector. More recently, Lazear (2005) defines entrepreneurship as incorporated self-employment. In addition, a scientist may not be self-employed but working for a small firm or new business that is engaged in entrepreneurial activity or working a second job that might potentially develop into an entrepreneurial venture. Thus, I measure entrepreneurship as self-employment, working a second job, working for a small firm, or working for a new business. These latter two definitions measure whether an individual is involved in an entrepreneurial venture whereas the first two measures are more closely associated with definitions of entrepreneurship found in the literature. I will examine the relationship between these entrepreneurial outcomes and the measures of innovation.

Academics, by definition, are not self-employed and do not bear the full financial risks of typical entrepreneurs. However, a significant number have second jobs related to their academic field. I assume that these second-jobholders are engaged in entrepreneurial activity provided the second job does not involve teaching. Previous research has assumed that patent applications and patents granted are measures of academic entrepreneurship. However, patent applications are less valid measures of entrepreneurship than patents granted or commercialized patents because the property

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[2] Employer size is available in all three survey years. The new business variable is available in the 2001 and 2003 waves of the SDR.

right has not been fully established and the monetary returns on the idea are less likely to be realized. It is the commercialization of the patent through licensing or the creation of commercialized products that results in profits related to entrepreneurship. However, commercialization of patents may not be related to holding a second job if the commercialization involves licensing the invention. Thus, the paper will explore the relationship between commercialization and holding a second job as an academic.

Table 1 presents mean characteristics of innovation and entrepreneurship in the academic sector.[3] The far right column in Table 1 shows the percentage of patents commercialized over total patents granted (for those that do patent). As expected, publications increase with academic rank. However, untenured associate and tenured full professors are the most likely to apply for and obtain patents. Scientists at Research I and academic medical centers have the highest rates of publication and patenting. Those who do patent, on-average commercialize approximately one-third of their discoveries. Although publication levels are lower at private universities on average, the number of patent applications is roughly similar to those found at Research I universities (however, the two categories do overlap). Interestingly, those who report having a second job in 1995 or 2001 also have higher publication rates, more patent applications, and the highest average commercialization rate relative to patents granted. Star publishers have more articles and more patent applications than those having a second job. This provides preliminary evidence that academic “stars” might be engaged in entrepreneurial activities. Life scientists and engineers are more likely to publish and patent than physical scientists, and the commercialization rate is highest among life scientists.

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[3] Appendix Table 1 provides a description of the variables used in this analysis.

Between 1995 and 2003 there has been a significant increase in the number of patent applications, patents granted, and patents commercialized. However, publications peaked in 2001 whereas patents increased through 2003.

Table 2 shows similar descriptive statistics for the industry sector by employer size, entrepreneurial activity, field, and year. Academics are more likely to publish than non-academics whereas non-academics are more likely to apply for patents and commercialize patents once-granted. Star publishers in industry make over three times the patent applications as those in academia. Ironically, the percentage of patents commercialized is actually lower. Interesting patterns of patenting emerge by firm size. Employees at very small firms (less than 10 employees) are less likely to be engaged in patenting. However, employees at small firms (10-100 employees) are more likely to patent than medium sized firms. Employees at larger firms (with more than 1000 employees) also make relatively higher numbers of patent applications. For employees that patent at smaller firms (less than 25 employees) over half of all patents are commercialized. In terms of entrepreneurial activity, employees at new businesses or those who are incorporated self-employees make the most patent applications. Over half the patents held by the incorporated self-employed have been commercialized. Patent applications and grants are highest among physical scientists and engineers in the non-academic sector. The commercialization rates are roughly similar across these fields. Similar to the academic sector, patent applications increased through 2003.

Taken together the descriptive statistics in Tables 1 and 2 indicate a correlation between innovation and entrepreneurial activity. The next sections investigate these relationships in greater detail.

III. Estimation Methods

The analysis begins with an examination of the factors associated with patent applications, patent grants, and patent commercialization in the academic and industry sectors. Since these outcomes are counts truncated at zero, a negative binomial model is estimated where the patent outcome, y, is a function of observable characteristics X. I include variables typically found in human capital model estimates in X. Explanatory variables include demographics, PhD field, employer characteristics, and firm-specific human capital proxied by work activities on the primary job. In addition, X contains measures of publications which are highly correlated with patent outcomes and endogenous in the equation. In this first set of analyses, I ignore the endogeneity issues in order to focus on the correlations associated with patenting outcomes. Endogeneity will be addressed after these empirical associations are established.

The second part of the analysis examines the correlation between innovation and entrepreneurship by estimating probit models of the effect of patenting (the measure of innovation) on entrepreneurial outcomes. Entrepreneurship is defined differently across the sectors. In the academic sector, entrepreneurship is defined as the probability of having a second job that is related to science and does not involve teaching. In the industry sector, I define entrepreneurship using three different measures: 1) incorporated self-employment;[4] 2) employment in a small firm with less than 100 employees; and 3) employment in a business that is less than five years old.[5]

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[4] This is the definition of entrepreneurship in Lazear (2005).

[5] In results not reported, I investigated the effect of innovation on unincorporated self-employment and working a second job in the industry sector. The number of scientists engaged in these activities in the sample did not produce statistically meaningful results.

Innovation may also be associated with exit from academic careers. I estimate the probability that tenure track academics have left academia permanently as a function of publication and patenting behavior. This allows me to evaluate whether innovation is linked with moving to the industry sector in order to facilitate the economic rewards of scientific discovery. This second set of analyses does not control for the potential endogeneity of patents in the entrepreneurship estimates. These first two sets of estimates pool data from all three years of the SDR.

The third set of regressions uses panel data from the SDR and fixed-effects methods to examine the causal question: Does innovation lead to entrepreneurship? To the extent that patenting behavior is endogenous to the entrepreneurship decision, the probit estimates above will be biased. Consider the model of the effect of patenting on the probability of entrepreneurship. Let y_{it} measure the entrepreneurship outcome, where i indexes individuals and t indexes time. Let X_{it} be characteristics that vary across individuals and time, and P_{it} be patent status. Consider the model:

$$\Pr(y_{it} = 1 \mid X_{it}, P_{it}) = \beta X_{it} + \gamma P_{it} + \varepsilon_{it}.$$

I can decompose the error term into two components: $\varepsilon_{it} = \eta_i + \upsilon_{it}$, where η_i is the individual-specific component, and υ_{it} is random error. If η_i is correlated with patent status and υ_{it} is uncorrelated with it, then using a conditional logit model will control for the unobserved individual heterogeneity. Under these assumptions, this procedure eliminates any observed or unobserved variables that do not vary by the individual. Conditional logit models estimate the probability of entrepreneurship in the academic and industry sectors and the probability of leaving tenure track academia as a function of patents, publications, and additional covariates.

IV. Empirical Results

The empirical analysis begins with a set of descriptive regressions that show the correlations between observable characteristics, innovation, entrepreneurship, and exiting academic careers. I focus initially on these descriptive results because few studies of innovation contain the detailed demographic, education, and career variables that are available in the SDR. The analysis then focuses on the causal relationship between innovation and entrepreneurship using fixed-effects methods to control for unobserved individual heterogeneity.

A. Factors Associated with Patenting

Tables 3 and 4 present negative binomial estimates of factors associated with patent applications, patents granted, and patents commercialized in the academic and industry sectors. The sample pools all three years of the SDR, and individuals may appear in the sample repeatedly; as a result all standard errors in Tables 3 and 4 are robust and clustered on the individual. Results for the academic sector are presented in Table 3. Two models are estimated for each outcome. The first model includes demographic characteristics, educational outcomes, academic rank, field of doctorate, employer characteristics, government support and year dummies. The second model adds measures of publications and paper presentations within the past five years, state dummies, whether the individual is a star publisher, and work activities. Ginther and Rassier (2005) have shown that work activities are measures of firm-specific human capital.

The results in Table 3 show that women, blacks, and untenured faculty are significantly less likely to apply for, to receive, or to commercialize patents. Individuals with PhD degrees in computer science and mathematics and earth science are also significantly less likely to patent.

Several demographic and employer characteristics are positively associated with patenting in the academic sector. Foreign-born academics are significantly more likely to apply for and obtain patents. However, the effect is no longer significant after controlling for publications and presentations. Marriage and children have a positive impact on patenting as does experience and having a PhD from a Research I institution. Tenured associate professors are significantly more likely to apply for and commercialize patents than any other academic rank. Together with the effect of experience, these results suggest that patenting happens in mid-career. Employment at a Research I or medical institution is positively associated with patenting. Patents are significantly more likely in the PhD fields of chemistry and engineering. Physics and biological sciences are also positively associated with patenting but the significance of the estimates vary depending upon specification and outcome. Government grant support significantly increases patent applications and grants but has no effect on patents commercialized.

For all three outcomes, the second specification in Table 3 shows a positive and significant effect of publications and paper presentations on patenting.[6] However, star academic publishers are not significantly more likely to patent. This finding is somewhat at odds with Zucker, Darby et. al. I will investigate this relationship further when estimating the relationship between publications and patents on academic

[6] The positive association between publications and patents must be interpreted with caution because the two outcomes are highly correlated. I address these endogeneity issues below.

entrepreneurship. Estimates on the work activity variables suggest that primary work as a researcher (the omitted category) and secondary work as a researcher are both positively correlated with patenting.

Table 4 presents negative binomial estimates for patent applications, patents granted and patents commercialized in the industry sector. The first model includes demographic characteristics, educational outcomes, field of doctorate, occupation dummies, employer size, and year dummies. The second model adds measures of publications and paper presentations within the past five years, star publishers, state dummies, occupation, and work activities. The results in Table 4 show that the demographic factors associated with patenting in the industry sector are the same as in the academic sector—women and blacks are less likely to patent. Unlike the academic sector, the foreign born have no significant effect on patenting. Children have a positive effect on patents granted and commercialized, however marriage has no significant effect on patenting in the industry sector. Having a doctorate from a Research I institution or any field besides earth science increases the likelihood of patenting.

The second models in Table 4 show that Engineering, Science and Management occupations are positively correlated with patenting. However, the Civil Engineering occupation is negatively associated with patent applications, grants, and commercialization. Scientists working for very large employers (>500 employees) are less likely to patent. This result provides evidence in favor of Baumol's (2004) conjecture that small firms are responsible for innovation. Similar to the academic sector, papers published and presented are positively associated with patent applications and grants. However, only paper presentations are positively associated with patent commercialization. Star publishers in the nonacademic sector have a negative effect on patent applications. Again, the publication estimates must be interpreted with caution given the endogeneity of publications. I now investigate whether patents and publications are correlated with entrepreneurial activity.

B. Factors Associated with Entrepreneurship

Table 5 presents probit estimates of the probability of having a second job in the academic sector using the 1995 and 2001 waves of the SDR.[7] Marginal coefficients and robust standard errors clustered on the individual are reported. The first column of Table 5 includes only controls for patents, publications, star publishers, and presentations. The second column adds demographic, education, and academic rank variables. The third column adds employer information, government support, state dummies, and work activities.

In all three models patents granted and commercialized are positively associated with having a second job in academia. Commercialized patents increase the likelihood of having a second job by almost two percent. Publications are not significantly different from zero, whereas presentations have a positive and significant effect. As before, star publishers have no significant impact on academic entrepreneurship, results that are sharply at odds with Zucker, Darby et. al. Women, the foreign born, married, and untenured individuals are less likely to have second jobs. Academics with doctorates in physics are significantly less likely, however, engineers are significantly more likely to work second jobs. Individuals who work for private institutions are 1.4 percent more likely to have a second job.

[7] Questions about the second job were omitted from the 2003 SDR.

Lazear (2005) argues that entrepreneurs are much less likely to specialize and have a wide-range of skills. This argument is supported by the work activity estimates in the third column of Table 5. With the exception of primarily working in management or with a computer, all primary and secondary work activities have a positive and significant effect on having a second job, suggesting that a variety of skills contribute to entrepreneurial activity.

Table 6 presents the marginal coefficients from probit estimates of the probability of entrepreneurial activity in the industry sector. Entrepreneurship is measured by three outcomes: incorporated self-employment, working for a small firm (<100 employees), and working for a business formed within the last five years. The first two outcomes use all years of the SDR. Working for a new business is only available in the 2001 and 2003 waves of the SDR. Whereas patents were positively correlated with academic entrepreneurship, the effect on industry entrepreneurship depends upon the outcome. Patents granted have a negative and significant effect on self-employment, but patents commercialized have a positive and significant effect. Neither patent variable has a significant effect on working for a small firm, however, patents granted has a small, positive effect on working in a new business. Publications are significant and negatively associated with self-employment and small firm employment, but have no significant effect on new business employment. Star publishers are significantly more likely to be working in incorporated self-employment. In contrast, stars are less likely ($p<.10$) to be working for new businesses. In addition, individuals previously employed on the tenure track are more likely to be self-employed.

The second and third columns add more covariates causing some of the estimated relationships to change. Previously having a tenure track job is no longer associated with self-employment. Women and blacks are less likely to work for small firms or new businesses. Having a doctorate from a Research I institution makes a scientist less likely to be self-employed. Those with doctorates in computer science, chemistry, physics, and engineering are significantly less likely to be self-employed. However, biology doctorates are more likely to work in small firms and computer science doctorates are more likely to work for new businesses.

The effect of work activities on entrepreneurship varies by outcome. Primarily working as a teacher, with computers, or in other activities increases the likelihood of self-employment as does secondary work in management. Primary and secondary work with computers, secondary work in research and management increases the likelihood of self-employment and working in a new business. In addition top management occupations are also associated with these outcomes. The fact that so many work activities are positively associated with entrepreneurship provides support for Lazear's argument that entrepreneurs are generalists.

C. Innovation and Exit from Tenure Track Academia

Next, I examine whether innovation is associated with leaving tenure track academia in Table 7. The sample is limited to those who report ever holding a tenure track job, and I estimate the probability of leaving academia permanently. The first specification includes innovation measures, the second adds demographic and Ph.D. information, and the third adds work activities and state dummies. In all three specifications, patents granted are associated with a permanent exit from academia. However, publications and presentations are negatively associated with leaving the tenure track. I find no significant impact of star publications on any of these specifications. This indicates that successful publishers are more likely to remain in academia. Women and African-Americans are less likely to leave academia as are older academics. Those who report other and computer work activities are more likely to leave. The results suggest that innovation, measured by patents granted, is closely associated with leaving academic careers.

It is important to note that none of the previous estimates control for the endogeneity of innovation measures in the choice to patent or engage in entrepreneurial activities. The next section estimates the causal effect of innovation on entrepreneurial activity.

D. Does Innovation Lead to Entrepreneurship?

Tables 8 through 10 use conditional logit methods to control for unobserved individual heterogeneity in order to examine whether changes in innovation lead to entrepreneurship or exit from academic careers. If the publication and patent decision is correlated with unobserved individual characteristics, then controlling for this individual fixed-effect will provide unbiased estimates of the effect of patents and publications on the entrepreneurship decision.

Table 8 presents conditional logit estimates of the effect of patents, publications, and presentations on having a second job. The first three columns add patent applications, patent grants, and patent commercialization separately along with additional controls. The fourth column includes patents and commercialized patents in the same specification. The final column includes publications and presentations as well. The star variable is included in the individual fixed effect. Recall that in Table 5 patents granted and commercialized and presentations were positively correlated with having a second job in the academic sector. The results in Table 8 show that the commercialization of patents increases the likelihood of having a second job by 73 percent in column three. Once I control for publications and presentations, the coefficient on patent commercialization increases the likelihood of having a second job to 91 percent and is significant at the one percent level. Having obtained a patent is not significant in any of the specifications. These results suggest that patent applications and patent grants, measures widely used in the literature, may be poor proxies for academic entrepreneurship.

The commercialization of patents clearly leads to academic entrepreneurship in the form of having a second job and supports the findings in Zucker, Darby et. al. These results indicate that individuals with commercialized patents are involved in employment outside of academia. Although I cannot link these individuals to specific firms, as the case studies of biotechnology and nano technology in Zucker, Darby et. al. do, I demonstrate that patent commercialization leads to academic entrepreneurship in all scientific fields. The main conduit of academic entrepreneurship is patent commercialization and applies to all scientific fields. This is especially true in computer science and for those working primarily with computers or other work activities.

Table 9 presents the conditional logit estimates of the effect of patents and publications on industry entrepreneurship. Once I control for unobserved heterogeneity, patents, publications, and presentations have no significant effect on self-employment or working for a new business. However, obtaining a patent increases the likelihood that a person works for a small firm with less than 100 employees by around 5 percent. This patent effect is much smaller than that found in the academic sector. These results also differ significantly from the descriptive regression results presented in Table 6 where patents commercialized were positively associated with self-employment and patents granted were positively associated with working in a new business.

Taken together, the results in Tables 8 and 9 suggest that patent commercialization has a causal effect on academic entrepreneurship, and obtaining a patent has a causal effect on working for a small firm. To the extent that small firm employment is a reasonable measure of entrepreneurship, the results suggest that innovation does have a causal effect on entrepreneurial activity in both the academic and industry sectors, however, the effects are much more pronounced for the academic sector.

E. Does Innovation Cause Exit from Tenure Track Academia?

Finally, I examine whether innovation has a causal effect on leaving academic careers in Table 10. I limit the sample to those individuals who have ever had a tenure track job and then estimate a conditional logit model of whether they take a non-academic job at some point in the three surveys. As before, the star variable is included in the individual fixed effect. The results in Table 10 indicate that patents commercialized have a weak ($p<.10$) effect on exiting academia. Similar to the results in Table 8, working primarily with computers or other work activities have a strong, positive effect on leaving academia. Given the relatively weak effect of patents granted on exiting academic careers, the results suggest that innovation does not play as an important role in leaving academic careers.

V. Conclusions

This paper has examined whether innovation, measured by patents, leads to entrepreneurship in the academic and industry sectors as well as whether it leads to exit from academic careers. The study began by exploiting the comprehensive data available in the SDR including demographic characteristics, educational background, employer characteristics, academic rank, government support, and work activities to examine those factors associated with patenting and entrepreneurship. I find that the factors associated with patenting by US Ph.D. scientists are very similar across the academic and industry sectors. Women and minorities are less likely to patent. Foreign-born scientists are more likely to patent in academia. Marital status and children are also positively associated with patenting in the academic sector. Having a doctorate from a Research I institution also increases the likelihood of patenting in both sectors. Tenured associate professors are more likely to patent than any other rank. In both sectors, scientists with doctorates in engineering and chemistry are the most likely to patent. In the industry sector, scientists employed at small firms are the most likely to make patent applications. In both sectors, publications and presentations are positively associated with patenting. However, being a star publisher—in the top 10^{th} percentile of publishing in the SDR—has no significant effect on patenting in either academic or industry sectors.

I also find that innovation, measured by patents granted and patents commercialized, is positively associated with academic entrepreneurship measured by having a second job. Publications and being a star publisher have no significant effect on academic entrepreneurship. In the industry sector, patents commercialized are positively correlated with incorporated self-employment and patents granted are positively associated with employment in a new business in the industry sector. Publications have a negative effect on being self-employed or working for a small business while having no significant effect on working for a new business. However, star publishers are significantly more likely to be self-employed. Patents granted are positively associated with exiting the tenure track. However these descriptive regression estimates are likely biased by the endogeneity of the publication and patenting decision.

I address this endogeneity using fixed-effects methods. After controlling for unobserved heterogeneity, the estimated relationship between innovation and entrepreneurship change significantly. In the academic sector, only the commercialization of patents has a large, positive effect on academic entrepreneurship measured by having a second job, whereas patents granted have no significant effect. Patents commercialized increase the likelihood of having a second job between 73 and 91 percent. In the industry sector, patents granted also have a positive effect on employment in a small, entrepreneurial firm but have no causal effect on incorporated self-employment or new business employment. However, the effect is much smaller than that found in academia. Thus, patents do not lead to self-employment, one often-used measure of entrepreneurship, but they are linked to employment at small firms that are most likely engaged in entrepreneurial activity. Finally, I find very limited evidence that innovation causes academics to leave the tenure track.

Why are the causal links between innovation and entrepreneurship stronger in the academy than industry? This may result from the ownership of the patent rights in academia. Typically, firms in industry hold the right to patents discovered by employees. Thus, an industry scientist is not free to take his patented research to other firms since his previous employer is the patent assignee. In academia, the scientist and university can share the property right to a patent or the scientist or the university can be the sole assignee. The property right of the patent depends on the negotiation between the university and the faculty member.[8] Given that the property rights of patents are less well-defined in academia, the commercialization of patents likely paves the way to entrepreneurial ventures by academic scientists.

These results have implications for research on academic entrepreneurship. Many researchers use patents granted as a measure of academic entrepreneurship. As I argue in the introduction, patent applications and patents granted may be poor proxies for entrepreneurship in academia because many patents are not commercialized, and commercialization may take the form of licensing to well-established firms. This paper supports this argument, suggesting that patent applications and patent grants will overstate academic entrepreneurship relative to measures that focus on patent commercialization.

The results in this paper support some of the conclusions of the case studies by Zucker, Darby et. al. In particular, the results in this paper substantiate Zucker, Darby et. al.'s findings that academic entrepreneurship is closely related to commercialization of scientific discoveries. The bulk of their research has focused on the biotechnology and

[8] For example, at the University of Kansas, profits from the commercialization of patents are split between the inventor, the inventor's department and the university.

nanotechnology industries. This research shows that commercialization of patents is the conduit for academic entrepreneurship in all science fields for a representative population of scientists.

Zucker, Darby, et. al. find that star academics (in terms of publications and citations) are associated with the commercialization and the success of biotechnology and nanotechnology new firms. However, I find no evidence of this in the academic sector. Although, I do find that star publishers are more likely to be self-employed in the nonacademic sector, these stars are less likely to leave academic science for industry. Results from Tables 9 and 10 suggest that stars in particular, and those that publish in general, are less likely to leave academic science. It could be that having a second job, used to measure academic entrepreneurship, does not capture the involvement of stars as measured by Zucker, Darby et. al. Alternatively, Zucker, Darby, et. al.'s focus on a single industry may overstate the effect of academic stars in entrepreneurship. Results from Tables 3 and 4 clearly show that star publishers have no significant effect on patenting. In fact, star publishers in industry are significantly less likely to patent. Moreover, the definition of star in this study and Zucker, Darby et. al. differs—with my definition likely being more broadly defined. One of these explanations or a combination of them may explain the discrepancy of these results.

Taken together, these results indicate that innovation does lead to entrepreneurship in both the academic and industry sectors. Baumol's "plausible observation" that innovators are associated with small business enterprises is borne out by the data, especially for the academic sector.

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Table 1: Average Measures of Innovation in Academic Sector
1995, 2001, and 2003 Survey of Doctorate Recipients

	Articles Published	Papers Presented	Number of Patent Applications	Number of Patents Granted	Number of Patents Comm.	Comm. / Total Patents
By Rank:						
Tenure-Track Assistant	6.926	10.306	0.196	0.106	0.034	0.320
Untenured Associate	8.787	12.780	0.424	0.207	0.076	0.368
Tenured Associate	8.013	11.463	0.205	0.120	0.043	0.308
Tenured Full	12.082	13.803	0.411	0.262	0.122	0.403
By Institution Type:						
Research I	10.753	12.658	0.398	0.228	0.095	0.355
Medical Center	10.210	11.113	0.381	0.202	0.078	0.364
Private University	7.930	9.551	0.348	0.204	0.084	0.319
Holds a Second Job	10.083	13.317	0.616	0.377	0.196	0.415
By Field:						
Life Science	8.690	10.296	0.241	0.123	0.050	0.369
Physical Science	8.087	9.810	0.231	0.141	0.052	0.307
Engineering	8.143	14.007	0.561	0.353	0.142	0.331
By Year:						
1995	8.097	9.900	0.196	0.118	0.043	0.327
2001	8.760	11.614	0.306	0.185	0.076	0.341
2003	8.498	11.008	0.405	0.214	0.087	0.359
Star Publisher	26.966	25.991	0.771	0.434	0.186	0.364

Table 2: Average Measures of Innovation in Industry Sector
1995, 2001, and 2003 Survey of Doctorate Recipients

	Articles Published	Papers Presented	Number of Patent Applications	Number of Patents Granted	Number of Patents Comm.	Comm. / Total Patents
By Employer Size:						
<10 Employees	2.005	3.511	0.883	0.603	0.259	0.513
10 - 24 Employees	2.533	4.640	1.261	0.823	0.354	0.504
25 - 99 Employees	3.001	4.468	1.617	0.766	0.341	0.444
100 - 499 Employees	3.276	4.885	1.161	0.624	0.275	0.444
500 - 999 Employees	2.873	4.890	1.175	0.594	0.227	0.398
1000-4999 Employees	3.302	4.533	1.310	0.787	0.319	0.416
5000 or more Employees	2.690	4.171	1.801	1.108	0.391	0.383
By Entrepreneurship:						
Self-Employed Unincorporated	1.771	3.007	0.630	0.556	0.244	0.477
Self-Employed Incorporated	1.584	3.353	0.967	0.594	0.322	0.542
New Business	2.985	4.437	2.395	1.116	0.452	0.430
Second Job	3.596	6.040	1.215	0.930	0.398	0.452
By Field:						
Life Science	3.703	4.895	0.916	0.429	0.187	0.401
Physical Science	2.657	3.888	1.788	1.161	0.390	0.382
Engineering	2.012	4.126	1.844	1.043	0.444	0.444
By Year:						
1995	3.058	4.458	1.109	0.684	0.247	0.399
2001	2.721	4.312	1.685	1.022	0.402	0.427
2003	2.404	3.978	1.948	1.042	0.413	0.403
Star Publisher	25.459	23.248	3.331	1.834	0.623	0.314

Table 3: Negative Binomial Estimates of Factors Associated with Patenting in Academic Sector 1995, 2001 and 2003 Survey of Doctorate Recipients

	Patent Apps.	Patent Apps.	Patents Granted	Patents Granted	Patents Comm.	Patents Comm.
Publications		0.020***		0.026***		0.024***
		[0.003]		[0.003]		[0.005]
Presentations		0.016***		0.013***		0.016***
		[0.002]		[0.002]		[0.003]
Star Publisher		0.141		0.04		0.031
		[0.092]		[0.104]		[0.145]
Female	-0.477***	-0.356***	-0.448***	-0.350***	-0.522***	-0.399***
	[0.092]	[0.077]	[0.101]	[0.096]	[0.153]	[0.139]
Age	-0.076***	-0.034***	-0.068***	-0.026***	-0.065***	-0.017
	[0.008]	[0.008]	[0.009]	[0.009]	[0.014]	[0.014]
Black	-0.491***	-0.164	-0.358*	-0.078	-0.590*	-0.212
	[0.169]	[0.171]	[0.190]	[0.194]	[0.348]	[0.355]
Other Race	0.799	0.758	-0.323	-0.15	-0.105	0.424
	[0.558]	[0.501]	[0.572]	[0.586]	[0.800]	[0.821]
Foreign Born	0.332***	0.075	0.354***	0.126	0.246*	-0.108
	[0.080]	[0.071]	[0.093]	[0.090]	[0.141]	[0.126]
Married	0.168*	0.154**	0.244**	0.197**	0.526***	0.423***
	[0.100]	[0.078]	[0.103]	[0.096]	[0.157]	[0.144]
Total Children	0.134***	0.075**	0.151***	0.090**	0.237***	0.190***
	[0.040]	[0.035]	[0.043]	[0.040]	[0.065]	[0.053]
Children < 6 Years	0.093	0.137	-0.046	0.096	-0.205	-0.034
	[0.085]	[0.084]	[0.102]	[0.108]	[0.173]	[0.164]
Years since PhD	0.119***	0.092***	0.144***	0.120***	0.145***	0.115***
	[0.015]	[0.015]	[0.018]	[0.018]	[0.026]	[0.024]
Years since PhD Squared	-0.001**	-0.001***	-0.001***	-0.001***	-0.001**	-0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
PhD from Research I	0.249***	0.193**	0.234**	0.269***	0.172	0.218
	[0.093]	[0.084]	[0.110]	[0.104]	[0.172]	[0.151]
PhD from Research II	-0.231*	-0.035	-0.237	0.022	-0.236	0.166
	[0.140]	[0.137]	[0.190]	[0.180]	[0.255]	[0.237]
Assistant Professor	-0.273***	0.155*	-0.08	0.327**	0.02	0.374**
	[0.095]	[0.089]	[0.123]	[0.132]	[0.185]	[0.176]
Untenured Associate Prof.	-0.481***	-0.217**	-0.358***	-0.105	-0.304*	-0.009
	[0.100]	[0.097]	[0.123]	[0.116]	[0.181]	[0.164]
Tenured Associate Prof.	0.360**	0.410***	0.291*	0.423**	0.524*	0.636**
	[0.160]	[0.147]	[0.169]	[0.179]	[0.274]	[0.253]
Full Professor	-0.094	-0.245**	-0.079	-0.224*	0.293*	0.134
	[0.104]	[0.107]	[0.128]	[0.126]	[0.177]	[0.167]

Notes: Robust Standard Errors clustered on individual in Brackets. * Significant at 5% level. ** Significant at 1% level.

Table 3: Negative Binomial Estimates of Factors Associated with Patenting in Academic Sector 1995, 2001 and 2003 Survey of Doctorate Recipients (continued)

	Patent Apps.	Patent Apps.	Patents Granted	Patents Granted	Patents Comm.	Patents Comm.
Computer Science / Mathematics	-0.594***	-0.05	-0.741***	-0.129	-1.046***	-0.355
	[0.202]	[0.183]	[0.237]	[0.223]	[0.308]	[0.304]
Biology and Environmental Sciences	0.459***	0.244*	0.375**	0.222	0.146	-0.08
	[0.163]	[0.147]	[0.180]	[0.169]	[0.229]	[0.235]
Chemistry	0.930***	1.061***	1.038***	1.264***	0.527*	0.715***
	[0.183]	[0.165]	[0.216]	[0.215]	[0.269]	[0.269]
Earth Sciences	-1.133***	-1.071***	-1.313***	-1.189***	-2.106***	-1.914***
	[0.296]	[0.276]	[0.375]	[0.346]	[0.718]	[0.708]
Physics	0.261	0.370**	0.483**	0.647***	0.232	0.499
	[0.192]	[0.181]	[0.224]	[0.216]	[0.297]	[0.308]
Engineering	1.172***	1.346***	1.294***	1.459***	0.964***	1.103***
	[0.166]	[0.149]	[0.188]	[0.174]	[0.244]	[0.241]
Research I		0.239***		0.273***		0.402***
		[0.068]		[0.080]		[0.120]
Private Institution		0.190**		0.185**		0.201
		[0.074]		[0.086]		[0.132]
Medical School		0.272***		0.242**		0.234*
		[0.080]		[0.094]		[0.132]
Government Support		0.251***		0.179**		-0.035
		[0.065]		[0.084]		[0.121]
Controls for Year	Yes	Yes	Yes	Yes	Yes	Yes
Controls for Work Activities	No	Yes	No	Yes	No	Yes
Controls for State	No	Yes	No	Yes	No	Yes
Observations	26079	26079	26079	26079	26079	26079

Notes: Robust Standard Errors clustered on individual in Brackets. * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table 4: Negative Binomial Estimates of Factors Associated with Patenting in Industry Sector 1995, 2001 and 2003 Survey of Doctorate Recipients

	Patent Apps.	Patent Apps.	Patents Granted	Patents Granted	Patents Comm.	Patents Comm.
Publications		0.026***		0.020***		0.001
		[0.006]		[0.006]		[0.006]
Presentations		0.026***		0.026***		0.027***
		[0.003]		[0.003]		[0.004]
Star Publishers		-0.381***		-0.221*		0.007
		[0.139]		[0.132]		[0.177]
Female	-0.570***	-0.517***	-0.585***	-0.505***	-0.623***	-0.550***
	[0.082]	[0.069]	[0.075]	[0.074]	[0.102]	[0.099]
Age	-0.059***	-0.041***	-0.039***	-0.025***	-0.039***	-0.028***
	[0.007]	[0.006]	[0.007]	[0.006]	[0.009]	[0.008]
Black	-0.449***	-0.362***	-0.474***	-0.407***	-0.593***	-0.519***
	[0.118]	[0.130]	[0.130]	[0.138]	[0.180]	[0.193]
Other Race	-0.101	0.016	0.195	0.356	-0.124	0.147
	[0.300]	[0.291]	[0.373]	[0.461]	[0.769]	[0.790]
Foreign Born	0.044	-0.049	0.078	0.02	0.073	0.011
	[0.055]	[0.050]	[0.061]	[0.057]	[0.076]	[0.070]
Married	0.072	0.044	0.047	0.02	0.044	0.034
	[0.081]	[0.070]	[0.076]	[0.077]	[0.098]	[0.094]
Total Children	0.019	0.037	0.065**	0.058**	0.070*	0.037
	[0.027]	[0.023]	[0.030]	[0.026]	[0.036]	[0.031]
Children < 6 Years	0.027	0.018	0.104*	0.114**	0.073	0.130*
	[0.056]	[0.050]	[0.059]	[0.057]	[0.075]	[0.070]
Years since PhD	0.128***	0.125***	0.196***	0.191***	0.206***	0.201***
	[0.012]	[0.010]	[0.013]	[0.012]	[0.017]	[0.016]
Years since PhD Squared	-0.002***	-0.002***	-0.003***	-0.004***	-0.004***	-0.004***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
PhD from Research I	0.201***	0.220***	0.257***	0.261***	0.109	0.084
	[0.071]	[0.060]	[0.075]	[0.066]	[0.082]	[0.080]
PhD from Research II	0.081	0.026	0.273**	0.216**	0.407**	0.218*
	[0.112]	[0.087]	[0.131]	[0.103]	[0.171]	[0.131]
Computer Science /	0.505***	0.901***	0.269	0.673***	0.044	0.259
Mathematics	[0.174]	[0.175]	[0.208]	[0.213]	[0.219]	[0.250]
Biology and Environmental	0.486***	0.251*	0.079	-0.17	-0.266	-0.447**
Sciences	[0.160]	[0.151]	[0.174]	[0.166]	[0.200]	[0.212]
Chemistry	1.324***	0.928***	1.375***	0.883***	0.724***	0.335
	[0.154]	[0.154]	[0.172]	[0.172]	[0.190]	[0.219]
Earth Sciences	-0.247	-0.23	-0.496	-0.530*	-0.529	-0.706**
	[0.293]	[0.260]	[0.319]	[0.272]	[0.400]	[0.353]
Physics	0.775***	0.625***	0.683***	0.455**	0.197	0.018
	[0.170]	[0.176]	[0.189]	[0.194]	[0.207]	[0.244]
Engineering	1.067***	0.970***	1.069***	0.914***	0.761***	0.529**
	[0.152]	[0.155]	[0.171]	[0.174]	[0.190]	[0.220]

Table 4: Negative Binomial Estimates of Factors Associated with Patenting in Industry Sector 1995, 2001 and 2003 Survey of Doctorate Recipients (continued)

	Apps.	Apps.	Granted	Granted	Comm.	Comm.
Computer/Mathematics		0.710*		0.431		0.641
Occupation		[0.388]		[0.386]		[0.500]
Biological / Medical		1.213***		1.003***		0.802
Occupation		[0.391]		[0.382]		[0.502]
Other Life Science		1.250***		0.917**		0.975*
Occupation		[0.426]		[0.399]		[0.517]
Chemistry Occupation		1.473***		1.447***		1.282**
		[0.388]		[0.385]		[0.501]
Physics Occupation		1.109***		1.140***		1.022**
		[0.397]		[0.394]		[0.508]
Physical Science		0.467		0.372		0.378
Occupation		[0.423]		[0.424]		[0.553]
Chemical Engineering		0.332***		0.287**		0.320*
Occupation		[0.107]		[0.129]		[0.181]
Civil Engineering		-1.658***		-1.582***		-1.428**
Occupation		[0.455]		[0.543]		[0.610]
Electrical Engineering		0.462***		0.403***		0.430***
Occupation		[0.084]		[0.102]		[0.136]
Mechanical Engineering		0.055		-0.043		0.189
Occupation		[0.129]		[0.139]		[0.184]
Top/Mid-Level Management		1.438***		1.310***		1.555***
Occupation		[0.386]		[0.382]		[0.497]
Other Management		1.246***		1.077***		0.961*
Occupation		[0.399]		[0.401]		[0.518]
Non-Science Occupation		0.816**		0.759**		0.857*
		[0.388]		[0.383]		[0.500]
Other Engineering		0.904**		0.831**		0.803
Occupation		[0.388]		[0.386]		[0.504]
Employer Size 10-24		-0.125		-0.022		0.062
		[0.107]		[0.133]		[0.154]
Employer Size 25-99		0.109		-0.136		-0.08
		[0.089]		[0.086]		[0.106]
Employer Size 100-499		-0.168*		-0.233**		-0.181
		[0.091]		[0.099]		[0.113]
Employer Size 500-999		-0.236**		-0.422***		-0.442***
		[0.117]		[0.111]		[0.138]
Employer Size 1000-4999		-0.248***		-0.303***		-0.257**
		[0.075]		[0.083]		[0.104]
Employer Size 5000+		0.044		0.004		-0.027
		[0.059]		[0.071]		[0.088]
Controls for Years	Yes	Yes	Yes	Yes	Yes	Yes
Controls for Work Activities	No	Yes	No	Yes	No	Yes
Controls for States	No	Yes	No	Yes	No	Yes
Observations	25636	25636	25636	25636	25636	25636

Notes: Robust Standard Errors clustered on individual in Brackets. * Significant at 10% level. **Significant at 5% level. *** Significant at 1% level.

Table 5: Probit Estimates of Probability of Second Job in Academic Sector, 1995 and 2001 Survey of Doctorate Recipients

	2nd Job	2nd Job	2nd Job
Patents Granted	0.008**	0.007**	0.007**
	[0.004]	[0.003]	[0.003]
Patents Commercialized	0.017**	0.015**	0.016**
	[0.007]	[0.006]	[0.006]
Publications	0.000	0.000	0.000
	[0.000]	[0.000]	[0.000]
Presentations	0.001***	0.001***	0.001***
	[0.000]	[0.000]	[0.000]
Star Publisher	0.002	-0.005	0.000
	[0.009]	[0.008]	[0.008]
Year = 2001	-0.009**	-0.010**	-0.010**
	[0.004]	[0.004]	[0.004]
Female		-0.014***	-0.016***
		[0.005]	[0.005]
Age		0.004***	0.003***
		[0.000]	[0.000]
Black		-0.008	-0.006
		[0.010]	[0.010]
Foreign Born		-0.054***	-0.054***
		[0.005]	[0.005]
Married		-0.017**	-0.014**
		[0.007]	[0.006]
Total Children		0.014***	0.014***
		[0.003]	[0.003]
Children < 6 Years		-0.005	-0.007
		[0.006]	[0.006]
Years since PhD		0.001	0.001
		[0.001]	[0.001]
Years since PhD Squared		-0.000***	-0.000***
		[0.000]	[0.000]
PhD from Research I		-0.006	-0.004
		[0.006]	[0.006]
PhD from Research II		-0.007	-0.004
		[0.009]	[0.009]
Assistant Professor		-0.031***	-0.035***
		[0.006]	[0.006]
Untenured Associate Prof.		-0.01	-0.013*
		[0.007]	[0.007]
Tenured Associate Prof.		-0.021*	-0.027**
		[0.012]	[0.011]
Full Professor		0.005	0.003
		[0.008]	[0.008]

Table 5: Probit Estimates of Probability of Second Job in Academic Sector
1995 and 2001 Survey of Doctorate Recipients (continued)

	2nd Job	2nd Job	2nd Job
Computer Science /		-0.01	-0.020*
Mathematics		[0.012]	[0.011]
Biology and Environmental		-0.005	-0.013
Sciences		[0.011]	[0.011]
Chemistry		-0.019	-0.025**
		[0.012]	[0.011]
Earth Sciences		-0.024*	-0.030**
		[0.013]	[0.012]
Physics		-0.033***	-0.037***
		[0.011]	[0.010]
Engineering		0.049***	0.041***
		[0.015]	[0.015]
Research I			0.004
			[0.005]
Private Institution			0.014**
			[0.006]
Medical School			-0.002
			[0.006]
Government Support			-0.006
			[0.005]
Primary work--Teaching			0.029***
			[0.008]
Primary work--Management			-0.002
			[0.008]
Primary work--Other			0.077***
			[0.013]
Primary work--Computer			0.013
			[0.020]
Secondary work--Research			0.032***
			[0.011]
Secondary work--Teaching			0.037***
			[0.014]
Secondary work--Management			0.025**
			[0.013]
Secondary work--None			0.038**
			[0.017]
Secondary work--Other			0.110***
			[0.021]
Controls for States	No	No	Yes
Observations	18718	18703	18703

Notes: Coefficients are marginal changes in probability. Robust Standard Errors clustered on individual in brackets. * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table 6: Probit Estimates of the Probability of Entrepreneurial Activity in Industry Sector 1995, 2001 and 2003 Survey of Doctorate Recipients

	Self-Employed	Self-Employed	Self-Employed	Small Firm	Small Firm	Small Firm	New Business	New Business	New Business
Number of Patents	-0.007***	-0.004***	-0.002**	-0.002	0.000	0.001	0.002*	0.001	0.002*
	[0.002]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Patents Commercialized	0.007***	0.005***	0.003***	0.002	0.001	-0.001	-0.001	-0.001	-0.002
	[0.002]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Articles Published	-0.005***	-0.004***	-0.002***	-0.001	-0.001	0.000	0.001*	0.001*	0.001
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Papers Presented	0.001	0.001*	0.000**	0.000	0.000	0.000	0.000	0.000	0.000
	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]	[0.000]	[0.001]	[0.000]	[0.000]
Star Publishers	0.116***	0.091***	0.045**	-0.006	-0.002	-0.009	-0.034*	-0.027	-0.026
	[0.037]	[0.033]	[0.023]	[0.022]	[0.023]	[0.020]	[0.019]	[0.019]	[0.016]
Ever Tenure Track	0.018**	0.006	-0.002	0.005	0.001	-0.005	-0.007	-0.007	-0.005
	[0.008]	[0.006]	[0.005]	[0.012]	[0.012]	[0.011]	[0.011]	[0.011]	[0.010]
Female		-0.002	-0.005		-0.046***	-0.044***		-0.023***	-0.022***
		[0.004]	[0.004]		[0.008]	[0.008]		[0.008]	[0.007]
Age		0.002***	0.002***		0.002*	0.001		-0.004***	-0.004***
		[0.000]	[0.000]		[0.001]	[0.001]		[0.001]	[0.001]
Black		0.017	0.016		-0.035**	-0.029*		-0.016	-0.019
		[0.012]	[0.011]		[0.017]	[0.016]		[0.017]	[0.014]
Other Race		0.043	0.001		0.370*	0.381*			
		[0.087]	[0.044]		[0.204]	[0.223]			
Foreign Born		0.004	0.007*		0.010	0.009		0.030***	0.023***
		[0.004]	[0.004]		[0.008]	[0.008]		[0.009]	[0.008]
Married		0.001	0.002		-0.034***	-0.027***		0.001	0.001
		[0.005]	[0.004]		[0.010]	[0.009]		[0.009]	[0.008]
Total Children		0.001	0.001		-0.001	0.000		-0.009**	-0.007**
		[0.002]	[0.002]		[0.004]	[0.003]		[0.004]	[0.003]
Children < 6 Years		-0.004	-0.004		0.007	0.005		0.008	0.007
		[0.004]	[0.004]		[0.008]	[0.008]		[0.010]	[0.009]

Table 6: Probit Estimates of the Probability of Entrepreneurial Activity in Industry Sector 1995, 2001 and 2003 Survey of Doctorate Recipients (continued)

	Self-Employed	Self-Employed	Self-Employed	Small Firm	Small Firm	Small Firm	New Business	New Business	New Business
Years since PhD		0.002**	0.002**		-0.009***	-0.010***		-0.004	-0.004
		[0.001]	[0.001]		[0.002]	[0.002]		[0.003]	[0.003]
Years since PhD Squared		-0.000**	-0.000**		0.000***	0.000***		0.000*	0.000*
		[0.000]	[0.000]		[0.000]	[0.000]		[0.000]	[0.000]
PhD from Research I		-0.020***	-0.016***		0.012	0.001		0.018*	0.005
		[0.006]	[0.005]		[0.009]	[0.009]		[0.010]	[0.010]
PhD from Research II		-0.007	-0.007		-0.009	-0.015		0.003	-0.007
		[0.006]	[0.005]		[0.013]	[0.012]		[0.015]	[0.013]
Computer Science /		-0.023***	-0.016***		-0.021	-0.016		0.049*	0.017
Mathematics		[0.006]	[0.006]		[0.019]	[0.020]		[0.027]	[0.024]
Biology and Environmental		0.003	-0.001		0.022	0.011		0.009	-0.011
Sciences		[0.009]	[0.007]		[0.019]	[0.018]		[0.018]	[0.017]
Chemistry		-0.025***	-0.020***		-0.040**	-0.025		-0.016	-0.017
		[0.006]	[0.006]		[0.017]	[0.018]		[0.017]	[0.017]
Earth Sciences		0.010	0.013		0.043	0.012		-0.027	-0.031*
		[0.014]	[0.014]		[0.031]	[0.027]		[0.020]	[0.017]
Physics		-0.016**	-0.014**		-0.013	-0.014		-0.025	-0.030**
		[0.007]	[0.006]		[0.020]	[0.020]		[0.016]	[0.015]
Engineering		-0.021***	-0.016**		-0.022	-0.006		0.009	0.009
		[0.007]	[0.007]		[0.017]	[0.018]		[0.018]	[0.019]
Primary work--Teaching			0.091**			-0.004			-0.009
			[0.043]			[0.040]			[0.041]
Primary work--Management			0.008*			0.007			-0.001
			[0.004]			[0.008]			[0.008]
Primary work--Other			0.051***			0.054***			-0.001
			[0.008]			[0.012]			[0.011]
Primary work--Computer			0.022***			0.068***			0.011
			[0.008]			[0.015]			[0.013]
Secondary work--Research			-0.011**			0.017			0.019
			[0.005]			[0.012]			[0.013]

Table 6: Probit Estimates of the Probability of Entrepreneurial Activity in Industry Sector 1995, 2001 and 2003 Survey of Doctorate Recipients (continued)

	Self-Employed	Self-Employed	Self-Employed	Small Firm	Small Firm	Small Firm	New Business	New Business	New Business
Secondary work--Teaching			0.008			0.045***			0.024*
			[0.005]			[0.013]			[0.014]
Secondary work--Management			-0.006			0.035**			0.017
			[0.006]			[0.017]			[0.018]
Secondary work--Computer			0.009			0.054***			0
			[0.009]			[0.020]			[0.018]
Secondary work--Other			0.008			0.045***			0.024*
			[0.005]			[0.013]			[0.014]
Top/Mid-Level Management			0.018			0.086			0.091
Occupation			[0.021]			[0.055]			[0.074]
Other Management			0.025			0.037			0.058
Occupation			[0.026]			[0.052]			[0.075]
Controls for Years	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls for Occupations	No	No	Yes	No	No	Yes	No	No	Yes
Controls for State	No	No	Yes	No	No	Yes	No	No	Yes
Observations	16284	16284	16234	16284	16284	16284	8661	8655	8578

Notes: Coefficients are marginal changes in probability. Robust Standard Errors clustered on individual in brackets. Self-employed the probability of incorporated self-employment. Small-firm is the probability of being employed by a firm with <100 employees. New Business is the probability of being employed by a new business (<= 5 Years). This variable is only available in 2001 and 2003.
* Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table 7 Probit Estimates of Probability of Leaving Academic Sector, 1995, 2001, and 2003 Survey of Doctorate Recipients

	Left Academia	Left Academia	Left Academia
Patents Granted	0.013**	0.011**	0.005**
	[0.005]	[0.005]	[0.002]
Patents Commercialized	-0.005	-0.004	-0.004
	[0.006]	[0.005]	[0.004]
Publications	-0.004***	-0.005***	-0.003***
	[0.001]	[0.001]	[0.001]
Presentations	-0.003***	-0.003***	-0.002***
	[0.001]	[0.001]	[0.000]
Star Publisher	0.030*	0.027	0.012
	[0.017]	[0.017]	[0.013]
Year = 2001	0.001	-0.002	-0.006
	[0.004]	[0.005]	[0.003]
Year = 2003	-0.013***	-0.017***	-0.018***
	[0.004]	[0.005]	[0.004]
Female		-0.024***	-0.009
		[0.008]	[0.006]
Age		-0.003***	-0.001
		[0.001]	[0.001]
Black		-0.046***	-0.031***
		[0.010]	[0.007]
Foreign Born		0.154	0.056
		[0.143]	[0.093]
Married		0.004	-0.005
		[0.009]	[0.006]
Total Children		-0.011	-0.004
		[0.009]	[0.006]
Children < 6 Years		0.005	0.003
		[0.003]	[0.002]
Years since PhD		0.007***	0.002
		[0.002]	[0.001]
Years since PhD Squared		-0.000**	0.000
		[0.000]	[0.000]
PhD from Research I		-0.011	-0.004
		[0.010]	[0.007]
PhD from Research II		-0.022*	-0.003
		[0.012]	[0.010]

Table 7 Probit Estimates of Probability of Leaving Academic Sector, 1995, 2001, and 2003 Survey of Doctorate Recipients (continued)

	Left Academia	Left Academia	Left Academia
Computer Science / Mathematics		0.008	0.031*
		[0.020]	[0.018]
Biology and Environmental Sciences		0.013	0.01
		[0.017]	[0.013]
Chemistry		0.009	0.036*
		[0.022]	[0.022]
Earth Sciences		-0.038**	-0.015
		[0.017]	[0.015]
Physics		-0.006	0.009
		[0.020]	[0.018]
Engineering		0.024	0.038**
		[0.020]	[0.018]
Primary work--Teaching			-0.118***
			[0.006]
Primary work--Management			0.003
			[0.006]
Primary work--Other			0.086***
			[0.016]
Primary work--Computer			0.146***
			[0.030]
Secondary work--Research			-0.011
			[0.008]
Secondary work--Teaching			-0.077***
			[0.006]
Secondary work--Management			-0.012*
			[0.007]
Secondary work—Computer			0.010
			[0.012]
Secondary work—Other			-0.016*
			[0.009]
Controls for States	No	No	Yes
Observations	14158	14158	14093

Notes: Coefficients are marginal changes in probability. Robust Standard Errors clustered on individual in brackets. * Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table 8: Conditional Logit Estimates of the Effect of Patents and Publications on Second Jobs in Academic Sector 1995 and 2001 Survey of Doctorate Recipients

	2^{nd} Job	2^{nd} Job	2^{nd} Job	2^{nd} Job	2^{nd} Job
Patent Applications	0.175**				
	[0.080]				
Patents Granted		0.032		-0.112	-0.139
		[0.056]		[0.120]	[0.123]
Patents Commercialized			0.550**	0.645**	0.652***
		[0.222]	[0.253]	[0.253]	[0.253]
Publications		0.005			0.007
		[0.010]			[0.010]
Presentations		0.011			0.009
		[0.006]			[0.007]
Controls for:					
Demographics	Yes	Yes	Yes	Yes	Yes
Academic Rank	Yes	Yes	Yes	Yes	Yes
Institution Type	No	Yes	No	No	Yes
Work Activities	No	Yes	No	No	Yes
Observations	1078	1078	1078	1078	1078
Individuals	539	539	539	539	539

Notes: *Significant at 10% level. **Significant at 5% level. *** Significant at 1% level.

Table 9: Conditional Logit Estimates of the Effect of Patents and Publications on Entrepreneurship in Industry Sector
1995, 2001 and 2003 Survey of Doctorate Recipients

	Self-Employed	Self-Employed	Small Firm	Small Firm	New Business	New Business
Patents Granted	-0.081	-0.090	0.050**	0.049**	-0.052	-0.054
	[0.052]	[0.055]	[0.023]	[0.024]	[0.039]	[0.040]
Patents Commercialized	0.109	0.117	-0.045	-0.048	0.022	-0.013
	[0.078]	[0.083]	[0.039]	[0.040]	[0.102]	[0.105]
Publications	-0.038	-0.039	0.001	0.001	0.012	0.006
	[0.025]	[0.026]	[0.011]	[0.012]	[0.024]	[0.024]
Presentations	0.003	0.003	-0.007	-0.009	0.001	0.000
	[0.017]	[0.018]	[0.009]	[0.009]	[0.014]	[0.015]
Controls For:						
Demographics	Yes	Yes	Yes	Yes	Yes	Yes
Occupations	No	Yes	No	Yes	No	Yes
Work Activities	No	Yes	No	Yes	No	Yes
Observations	1430	1430	2906	2906	1192	1192
Individuals	571	571	1172	1172	596	596

Notes: Self-employed is the probability of incorporated self-employment. Small-firm is the probability of being employed by a firm with <100 employees. New Business is the probability of being employed by a new business (<= 5 Years). This variable is only available in 2001 and 2003. * Significant at 1% level. ** Significant at 5% level. *** Significant at 1% level.

Table 10: Conditional Logit Estimates of the Effect of Patents and Publications on Leaving Academic Sector, 1995, 2001 and 2003 Survey of Doctorate Recipients

	Left Academia	Left Academia
Patent Granted	-0.017	-0.038
	[0.070]	[0.080]
Patents Commercialized	0.189	0.350*
	[0.150]	[0.188]
Publications	-0.008	0.004
	[0.011]	[0.012]
Presentations	-0.005	-0.011
	[0.008]	[0.009]
Controls for:		
Demographics	Yes	Yes
Work Activities	No	Yes
Observations	988	988
Individuals	362	362

Notes: *Significant at 10% level. **Significant at 5% level.
*** Significant at 1% level.

Appendix Table 1: Definitions of Variables Used in this Analysis

Variable Name	Description	1995	2001	2003	Sector
Patents:					
Patent Applications	Number of Patent Applications within past 5 Years	X	X	X	Both
Patents Granted	Number of Patents Granted within past 5 Years	X	X	X	Both
Patents Commercialized	Number of Patents Commercialized within past 5 Years	X	X	X	Both
Entrepreneurship:					
Academic Second Job	Primary job Academia; Works 2nd Job	X	X		Academic
Self-Employed Unincorporated	Self-Employed Unincorporated = 1	X	X	X	Industry
Self-Employed Incorporated	Self-Employed Incorporated = 1	X	X	X	Industry
New Business	Employed by New Business = 1		X	X	Industry
Second Job	Primary job Industry; Works 2nd job	X	X		Industry
Publications	Number of Publications within past 5 Years	X	X	X	Both
Presentations	Number of Papers presented at conferences within past 5 Years	X	X	X	Both
Star Publisher	Published ≥ 15 papers in previous 5 years	X	X	X	Both
Explanatory Variables:					
Female	Female = 1	X	X	X	Both
Age	Age in Survey Year	X	X	X	Both
Black	African-American = 1	X	X	X	Both
Other Race	Non-Black, Non-White = 1	X	X	X	Both
Foreign Born	Foreign Born = 1	X	X	X	Both
Married	Married = 1	X	X	X	Both
Total Children	Total Number of Children in Survey Year	X	X	X	Both
Children < 6 Years	Children < 6 years = 1	X	X	X	Both
Years since PhD	Years since PhD	X	X	X	Both
PhD from Research I	Doctorate from Research I University = 1	X	X	X	Both
PhD from Research II	Doctorate from Research II University = 1	X	X	X	Both
Assistant Professor	Assistant Professor = 1	X	X	X	Academic
Untenured Associate Prof.	Untenured Associate Professor = 1	X	X	X	Academic
Tenured Associate Prof.	Tenured Associate Professor = 1	X	X	X	Academic
Full Professor	Full Professor = 1	X	X	X	Academic
Computer Science / Mathematics	Doctorate Field Computer Science / Mathematics	X	X	X	Both
Biology and Environmental Science	Doctorate Field Biology and Environmental Science	X	X	X	Both
Chemistry	Doctorate Field Chemistry	X	X	X	Both
Earth Sciences	Doctorate Field Earth Sciences	X	X	X	Both
Physics	Doctorate Field Physics	X	X	X	Both
Engineering	Doctorate Field Engineering	X	X	X	Academic
Research I	Academic Employer Research I = 1	X	X	X	Academic
Private Institution	Academic Employer Private Institution = 1	X	X	X	Academic
Medical School	Academic Employer Medical School = 1	X	X	X	Academic
Government Support	Receives Government Grants = 1	X	X	X	Academic

Appendix Table 1: Definitions of Variables Used in this Analysis (continued)

Variable Name	Description	1995	2001	2003	Sector
Explanatory Variables:					
Ever Tenure Track	Dummy for ever having a Tenure Track job	X	X	X	Industry
Primary work--Teaching	Primary Work on Main Job--Teaching = 1	X	X	X	Both
Primary work--Management	Primary Work on Main Job--Management = 1	X	X	X	Both
Primary work--Other	Primary Work on Main Job--Other = 1	X	X	X	Both
Primary work--Computer	Primary Work on Main Job--Computer = 1	X	X	X	Both
Secondary work--Research	Secondary Work on Main Job--Research = 1	X	X	X	Both
Secondary work--Teaching	Secondary Work on Main Job--Teaching = 1	X	X	X	Both
Secondary work--Management	Secondary Work on Main Job--Management = 1	X	X	X	Both
Secondary work--None	Secondary Work on Main Job--None = 1	X	X	X	Both
Secondary work--Other	Secondary Work on Main Job--Other = 1	X	X	X	Both
Computer/Mathematics Occupation	Computer/Mathematics Occupation = 1	X	X	X	Industry
Biological / Medical Occupation	Biological / Medical Occupation =1	X	X	X	Industry
Other Life Science Occupation	Other Life Science Occupation = 1	X	X	X	Industry
Chemistry Occupation	Chemistry Occupation = 1	X	X	X	Industry
Physics Occupation	Physics Occupation = 1	X	X	X	Industry
Physical Science Occupation	Physical Science Occupation = 1	X	X	X	Industry
Chemical Engineering Occupation	Chemical Engineering Occupation = 1	X	X	X	Industry
Civil Engineering Occupation	Civil Engineering Occupation = 1	X	X	X	Industry
Electrical Engineering Occupation	Electrical Engineering Occupation = 1	X	X	X	Industry
Mechanical Engineering Occupation	Mechanical Engineering Occupation = 1	X	X	X	Industry
Top/Mid-Level Management Occupation	Top/Mid-Level Management Occupation = 1	X	X	X	Industry
Other Management Occupation	Other Management Occupation = 1	X	X	X	Industry
Non-Science Occupation	Non-Science Occupation = 1	X	X	X	Industry
Other Engineering Occupation	Other Engineering Occupation = 1	X	X	X	Industry
Employer Size 10-24	Employer Size 10-24 = 1	X	X	X	Industry
Employer Size 25-99	Employer Size 25-99 = 1	X	X	X	Industry
Employer Size 100-499	Employer Size 100-499 = 1	X	X	X	Industry
Employer Size 500-999	Employer Size 500-999 = 1	X	X	X	Industry
Employer Size 1000-4999	Employer Size 1000-4999 = 1	X	X	X	Industry
Employer Size 5000+	Employer Size 5000+ = 1	X	X	X	Industry