Gender Differences in the Influence of Institutional Environments on Entrepreneurship

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Gender gaps are well-documented in U.S. natural sciences, technology, engineering, and mathematics (STEM) degree-granting programs, and among practicing scientists and engineers in the U.S. workforce. Female scientists and engineers are also less likely than males to apply for, receive, or commercialize patents, and to work in start-up firms or small businesses. Among STEM PhDs in the workforce in 2010, 5.4% of women and 7.0% of men were participating in entrepreneurial ventures. Combining multiple panel data sources and a nonlinear decomposition approach, this paper evaluates the relative importance of several potential contributors to the gender gap in science-based entrepreneurship. I find that less than one-quarter of the gap is attributable to differences in PhD field-of-degree, whereas almost half is attributable to gender differences in years of experience and propensity towards academic employment. In addition, about one-fifth of the gender gap in entrepreneurship is explained by differences in STEM PhDs' graduate and postdoctoral training environments, as well as short-run parenthood effects, both of which appear to impact women differently from men.

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I. Introduction

Women's continued underrepresentation in natural sciences, technology, engineering, and mathematics (STEM) fields has been well-documented (National Science Foundation, 2013). In their recent review of the gender and entrepreneurship literature, Jennings and Brush (2013) likewise found that, worldwide, women are much less likely than men to participate in entrepreneurship, across a variety of measures including self-employment, business ownership, founding or directing start-up companies, and commercialization of academic research. However, to date, most studies of gender gaps in STEM fields have tended to focus on women's lower enrollment and retention in STEM degree programs, rather than innovative or entrepreneurial outcomes among those who earn STEM degrees. Studies of gender differences in research productivity and innovative behaviors have also tended to focus on academic faculty, despite faculty members' relatively lower propensity to patent or commercialize inventions, as compared with their PhD-trained counterparts in industry (Whittington, 2011).

Hunt et al. (2013) and Whittington (2011) provide rare exceptions. Hunt et al. (2013) use 2003 National Survey of College Graduates data to demonstrate nearly one-third (31%) of the gender gap in patenting is attributable to specific fields-of-degree, with another 10% attributable to women's lower share of doctorates, especially in STEM fields such as electrical and mechanical engineering. Moreover, they find college-educated women are less likely than college-educated men to license or commercialize their granted patents. This difference in commercialization rates, they argue, is key, as licensed and commercialized patents are more likely to contribute to economic growth.

Whittington (2011) employed two waves (1995 and 2001) of the National Science Foundation's (NSF) Survey of Doctorate Recipients (SDR) to examine gender differences in STEM PhDs' patenting behavior, controlling for occupational research focus, publication counts, government funding, seniority, graduating cohort, and broad STEM field-of-degree. She finds the patenting gap by gender closed over this period, primarily driven by increased rates of ever-patenting among female academic scientists and engineers. At the same time, female faculty members' higher propensity to work teaching-focused positions (which are associated with lower rates of patenting), and correspondingly lower average research output (as measured by publication counts) contribute substantially to the remaining gap.

Building on these prior studies, in this paper I examine gender differences in STEM PhDs' participation both in patenting and in their subsequent entrepreneurial ventures, combining data from the 2008 and 2010 panel waves of the SDR with those individuals' matched NSF Survey of Earned Doctorates responses (collected around the time of PhD award), along with their PhD-granting institution's responses to the Survey of R&D Expenditures at Universities and Colleges, and newly constructed data on successful patent applications by those institutions, each year. Like Sauermann and Roach (2014), I expand our notion of participation in entrepreneurial ventures beyond self-employment and small business ownership, to include employment in start-up ventures, for example as part of a founding team. Incorporating these additional institutional data representing relative research intensity, funding sources, and exposure to patenting activities in STEM PhDs' graduate and postdoctoral training, I find substantial differences both within and across STEM fields in "what matters" for women's versus men's entrepreneurship.

A priori, one might expect that gender disparities in high-growth, science-based entrepreneurship could be attributed to a combination of women's lower share of postsecondary STEM degrees, their typically higher representation among the faculty in teaching-focused institutions, and their overall lower propensity towards self-employment. The more applied nature of engineering fields may also attract individuals with relatively greater economic or commercial orientation. But *within* any given STEM field, it is also possible that graduate and postdoctoral training environments might also influence STEM PhDs' subsequent career paths. Notionally, students who have opportunities to work on industry-sponsored research projects, and who observe their faculty mentors doing so, may be more comfortable and familiar with identifying commercial applications for their research (Behrens & Gray, 2001; Slaughter, Campbell, Holleman, & Morgan, 2002; Thune, 2010).

Along these lines, Bercovitz and Feldman (2008) found significant evidence of graduate school "imprinting" effects: medical school faculty members who had trained in departments that were active in engaging industry and in technology transfer activities were more likely to participate in technology transfer initiatives. Industry funding for graduate students may also increase likelihood of the students being hired by the funding firm, after completion of the PhD (Slaughter, et al., 2002). Moreover, if they subsequently return to academia, PhDs' time in industry may still influence faculty members' research productivity and commercialization efforts. Ding et al. (2006) found in their interviews of academic life scientists that, "regardless of gender, those that experienced patenting during [doctoral and postdoctoral] training were undaunted by the challenges of combining academic and commercial science." On the other hand, despite their overall finding that university scientists with prior industry experience tend to have lower productivity (as measured by publications), Lin and

Bozeman (2006) also mention that, for *female* academic scientists and engineers, prior industry experience had a positive effect on research productivity.

This paper extends these investigations more broadly, across STEM fields and across sectors of employment, examining not only patenting outcomes but also entrepreneurship. I find that differences in graduate and postdoctoral training environments explain a large fraction of the gender gap in entrepreneurship, even among individuals who share the same level of education and STEM degree field. Indeed, the gender gap in STEM PhDs' entrepreneurial venturing appears to owe at least as much to these factors, as to the field of degree itself.

Why is it important to understand the factors contributing to women's participation in science-based entrepreneurship? In 2010, U.S. small businesses paid for and performed over 18% of U.S. industry R&D, totaling over $40 billion, and they were also awarded 37% of U.S. industry patents. Consistent with this apparent discrepancy between aggregate expenditure and innovative impact, entrepreneurial firms have been credited with contributions to radical or "breakthrough" innovations disproportionate to their share of the nation's total R&D expenditures, and with stimulating economic growth through their introduction of new products and processes (Audretsch, 1995; Baumol, 2004, 2010). Small businesses are particularly active R&D contributors (and producers of intellectual property (IP)) in the pharmaceutical and biotechnology sectors, and in manufacture of computer and electronic products, components, and instruments.

In addition to their contributions to R&D and IP, small businesses also employed about 382,000 research scientists, engineers, and technicians in 2010, representing nearly one-third (31%) of the industrial research workforce (National Science Foundation & National Center for Science and Engineering Statistics, 2013). Numerous empirical studies have also found that new businesses account for a substantial share of employment growth. Using detailed U.S. Census Bureau data, Haltiwanger et al. (2013) importantly found that most of the employment growth attributed to small businesses is in fact due to start-up firms, which tend also to be small. Though start-up firms in their study account for only 3% of U.S. total employment, the authors find start-ups contribute almost 20% of new jobs created. Litwin and Phan's (2013) study using Kauffman Firm Survey data further shows that job quality, as measured by rates of benefits provision, is higher among innovative start-up companies, i.e., among those holding patents or claiming another source of competitive advantage.

Given the apparent importance of STEM-based entrepreneurship to the nation's economic growth, policymakers should reasonably be concerned by any evidence that suggests structural, practical, or perceptual barriers are discouraging interested, highly-skilled members of underrepresented groups from participating. In addition, despite women's overall lower rate of patenting, Whittington and Doerr (2008) find that male and female scientists who work in science-based entrepreneurial biotechnology firms are equally likely to patent, and conclude that participation in such firms may provide "a more equalizing environment" for women scientists. Whereas women working in more flexible, small, science-based innovative firms that emphasize collaboration and teamwork tend to be more productive, women scientists who work in traditional, hierarchical settings like academia may be marginalized relative to their male colleagues. If the productivity effect the authors observed holds for other STEM fields and industries, then encouraging women's participation in entrepreneurial ventures more broadly—whether as owners, or as employees in entrepreneurial ventures—may be particularly beneficial for innovation-driven economic growth.

II. Empirical Approach

For the purpose of this study, our definition of entrepreneurship is similar to that suggested by Lazear (2005), which focuses on individuals who were "among those who initially established the business." Operationally, we include in our definition individuals who identify as any of the following: small business owners; incorporated self-employed; unincorporated self-employed, who supervise one or more employees; and employees of new small business ventures, founded within the past five years, with fewer than 100 employees. As noted above, part of the motivation for using this broader definition derives from recent literature demonstrating women scientists' greater research productivity in collaborative, team-based environments (Kelchtermans & Veugelers, 2013; Whittington & Smith-Doerr, 2008).

Data and Descriptive Statistics

The Survey of Doctorate Recipients (SDR) is a biennial panel survey of individuals who earned PhDs at U.S. institutions since the mid-1970s, collected for the National Science Foundation (NSF). For this study, I obtained my core SDR datasets under NSF restricted-use license, via the National Opinion Research Center (NORC) Data Enclave. I also merged in individuals' linked responses from the NSF Survey of Earned Doctorates (SED) questionnaire, contained in the restricted-use Doctorate Records File (DRF), and then supplemented these data with institution-level information from the NSF's Survey of Research and Development Expenditures at Universities and Colleges, and university-assigned patent counts derived from U.S. Patent and Trademark Office (USPTO) data files.

Survey of Doctorate Recipients (SDR).—The 2010 SDR contains many demographic variables of interest for this analysis, including: current labor force status; sector of employment (including both incorporated and unincorporated self-employment, type of institution if employed in academia, and so on); employer size; whether their principal employer is a new firm that came into existence within the past five years; whether the respondent changed jobs within the previous two years (and if so, why); whether they are married or "living as married," and if so, whether their spouse or partner is employed, and if so, whether their spouse or partner's occupation requires a bachelor's or higher degree in a STEM field; how many children (dependents under age 19) live in their home, by age group; how closely related their job is to their first doctoral degree; and finally, their primary and secondary work activities, as well as which of several work activities they spend at least 10% of their time on, in a typical week.

From the 2008 SDR, in addition to several employment and family demographics variables noted above that are common to both survey waves, I also extracted responses from that wave's unique questions (not repeated in 2010) asking whether the individual had been named as inventor on any patent application within the previous five years (October 2003 through October 2008), and whether any patents they invented were licensed or commercialized over that same five-year period. One advantage of using the five-year "recent patents" outcome variable is that, unlike cumulative career patent counts, it permits us to test existence of impacts directly related to presence of young children in the home, rather than presuming parenthood also changes scientists' long-run inventive trajectory.

Doctorate Records File (DRF).—Respondents with postdoctoral training or employment with industry were identified using their SDR-linked responses to the NSF Survey of Earned Doctorates (SED), a census of U.S.-earned research doctorates administered around the time each respondent graduates from his or her STEM PhD program. Each year's SED responses are added to the cumulative

Doctorate Records File (DRF) dataset, also available from NSF under restricted-use license. SED respondents comprise the sampling frame for the SDR data described above, allowing for essentially complete matching via the SDR-DRF link file.

From the linked DRF data, I extracted variables capturing respondents' employment plans at time of graduation, recoding specifically to investigate whether having one's first postdoctoral employment in industry, or having postdoctoral funding support (e.g., for a postdoctoral research fellowship) provided by industry, increased the probability of subsequent patenting or entrepreneurship. My constructed industry postdoc dummy variable represents individuals who indicated that, by the time they graduated, they had signed a contract or otherwise had a definite, firm commitment for a specific position (including postdoctoral fellowships), with a specific employer, and who further said they were either going to work for business or industry, or take a postdoctoral fellowship for which the primary financial support came from industry sources.

Over the past several years, news media have reported anecdotes of entrepreneurs, particularly in the information technology sector, who chose to drop out of college citing the desire to avoid acquiring excessive student loan debt. At the same time, student higher education debt has only continued to increase, with popular media drawing parallels to the housing mortgage crisis. However, to the best of my knowledge, to date no rigorous empirical study examining the relationship between individuals' student debt load and their propensity towards entrepreneurship has been performed. The SDR-DRF data contain categorical variables for accumulated student debt loads at time of graduation. I recoded these categories for consistency across survey years, and include debt at time of graduation in the empirical models that follow.

Other Data Sources.—Additional key explanatory variables to capture aspects of respondents' graduate training environments were merged on the individual's PhD-granting institution, doctoral research field, and graduation year. From the NSF Survey of Research and Development Expenditures at Universities and Colleges (predecessor to the current Higher Education R&D Survey), I matched total (i.e., all funding sources) and non-federally-funded R&D for the respondent's doctoral institution and field, as of the fiscal year in which the respondent earned his or her doctorate.

Finally, I incorporated university-assigned patent counts derived from USPTO records, which reflect the number of successful patent applications the university filed each year. These data are described in more detail elsewhere (Blume-Kohout, Kumar, & Sood, 2014), but include campus-level assignments for the University of California and University of Texas, as well as several other university systems. Because some smaller institutions have relatively large year-to-year fluctuations in their patent applications, I smooth the university patents variable, taking the average over the number of successful patent applications submitted by the university in the year the student graduated, and for the four years preceding.

Descriptive Statistics.—Descriptive statistics by gender for our outcome variables and key explanatory variables are presented in Table 1.

Overall, about 1 in 4 STEM PhDs (24.6%) in our analytic sample reported in the 2008 SDR that they had been named as inventor on one or more patent applications filed over the five-year period October 2003 through 2008. However, male STEM PhDs were significantly and substantially more likely to have filed one or more patents: 28.4% of men and 15.0% of women reported having done so over the specified lookback period. Men were also more than twice as likely to have licensed or commercialized a patent during that period (10.3% versus 4.1%).

TABLE 1. DESCRIPTIVE STATISTICS FOR SURVEY OF DOCTORATE RECIPIENTS ANALYTIC DATASET

	Women	Men	Sig. Diff. ?
Entrepreneurs, all groups	5.43%	7.04%	***
Self-employed, unincorporated	1.46%	1.11%	***
Small business owner	2.76%	3.60%	***
Employed by startup company	1.21%	2.33%	***
Filed 1 or more patents as inventor, 2003-2008	15.0%	28.4%	***
Licensed/commercialized a patent, 2003-2008	4.07%	10.3%	***
Years since PhD awarded (average), 2010	11.1 yrs	11.9 yrs	***
Working for academic institution, 2008	47.4%	37.2%	***
Percent of academics with tenure as of 2003	7.97%	13.4%	***
Research-intensive occupation, 2008	67.9%	75.6%	***
Racial/ethnic minority	7.59%	5.46%	***
Foreign, temporary resident, 2010	3.54%	2.69%	***
Married, 2010	79.5%	88.3%	***
Child under age 6 at home, 2008	29.8%	33.0%	***
Child under age 2 at home, 2010	9.69%	11.2%	**
PhD institution's percent non-federal R&D, in field and year PhD was awarded	36.3%	37.8%	**
Postdoc employment w/ industry	3.07%	4.15%	p=.12
Earned MBA or similar after PhD	< 1%	< 1%	No
Bachelor's degree same field as PhD	64.2%	64.1%	No
Attended Carnegie "R1" institution	80.3%	80.9%	No
$30K or more in education debt at graduation	6.28%	5.84%	No

*** $p < .01$ ** $p < .05$ *$p < .10$

Survey-weighted descriptive statistics for analytic dataset, comprising 8,829 respondents who completed PhDs in STEM fields at U.S. institutions between 1990 and 2006.

Data sources: Survey of Doctorate Recipients (SDR) 2008 & 2010; Survey of Earned Doctorates – Doctorate Records File, 1990-2007; Survey of R&D Expenditures at Universities and Colleges, 1985-2007; U.S. Patent and Trademark Office (USPTO) records for patents awarded 1985-2012.

Male STEM PhDs are also significantly more likely than female PhDs to report that their primary work activity is basic research, applied research, development or design, related to their PhD field. Among those employed by established organizations, 50% of men and 45% of women engaged in these most R&D-intensive jobs, doing work they said was "closely related" to their PhD (difference highly significant, $p<.0001$). By contrast, only 1 in 3 (31%) STEM PhD-entrepreneurs primarily work on R&D activities, and in occupations closely related to their PhD, with no significant difference for men versus women. Interestingly, both women and men who chose employment in start-up ventures were significantly more likely (40% vs. 30%) than those working for established organizations to say their occupation is only "somewhat related" to their PhDs. But, whether or not they say their occupation is "closely related" to their PhD, about 60% of STEM PhDs working for startups still report their job activities include "development"—that is (per the survey instrument), using knowledge gained from research to produce materials or devices. Reflecting the more varied activities and generalist skill set typically attributed to entrepreneurs, over 60% of STEM PhD small business owners spend several hours each week managing people or projects, as well as at least 10% of their time on accounting and finance-related tasks.

Other notable descriptive differences presented in Table 1 include women's substantially higher probability of working for an academic institution (47.4% versus 37.2%), and their typically lower experience and seniority. In addition, 4.2% of men, versus 3.1% of women, had industry-supported postdoctoral employment immediately following their PhDs (test for statistical significance of difference $p=.12$).

Men and women were equally likely to have attended a Carnegie "R1" highly research-intensive university, but men were more slightly more likely to attend institutions where a higher share of their field's total R&D expenditures were funded by industry and other non-federal sources.[1] On the other hand, we see no difference between male and female STEM PhDs in their tendency to pursue MBAs or similar business or management degrees after the PhD, nor in the share of PhDs whose doctorates were earned in a different field than their bachelor's degree. We also observe no statistically significant difference between male and female STEM PhDs in the share—approximately 6% of both groups—who had acquired postsecondary student debt loads of $30,000 or more by the time they graduated.

Finally, female STEM PhDs were less likely to be married, and less likely to have young children at home, compared with their male colleagues. Female STEM PhDs were also significantly more likely to be from historically underrepresented racial or ethnic groups (7.6% versus 5.5%), or foreign nationals on temporary resident visas (3.5% versus 2.7%).

Modeling Approach

The empirical analyses presented below decompose the relative contributions of several potential factors associated with the gender gaps in patenting and entrepreneurship, respectively. Because the outcome variables in each case are binary, and especially because the entrepreneurship outcome is relatively rare, logistic or probit models are preferable to linear probability models. Like Fairlee (1999), I employ a Oaxaca-type nonlinear decomposition approach in each case.

[1] Within-field, however, the difference is more stark. Blume-Kohout (2014) shows that female STEM graduate students more often attend lower-ranked graduate programs with a smaller share of students supported by industry or other external private sector sources, and with higher ratios of undergraduates to graduate enrollment. In chemical and mechanical engineering, female graduate students appear preferentially to enroll in graduate programs with no industry-funded R&D.

STEM Degree Field.—Many prior studies have found higher education, as a form of human capital investment, increases the probability of entrepreneurial activity (Aldridge, Audretsch, Desai, & Nadella, 2014). Recent studies have also demonstrated substantial variation in the ways in which academic scientists engage with industry and also in scientists' entrepreneurship across STEM fields (Aldridge, et al., 2014; Blume-Kohout, 2014; Perkmann et al., 2013). For both outcomes, I therefore begin by explicitly accounting for differences in the distribution of PhDs earned by gender, across STEM fields, via inclusion of field-specific constants (i.e., "dummy variable" fixed effects) corresponding to research doctorates earned in each of the following fields: aerospace engineering, agricultural sciences, biological sciences, chemistry, chemical engineering, civil engineering, computer science, earth & environmental sciences (includes atmospheric sciences, geology, oceanography, and other environmental sciences), electrical engineering, mathematics and statistics, materials science and other/unspecified engineering fields, mechanical engineering, medical sciences, and physics and astronomy.

Age, Rank, and Experience.—Accumulated professional experience, seniority, and aging have generally been found predictive of differences in research productivity and commercial research activities. Early work by Levin and Stephan (1991) demonstrated a nonlinear effect of aging on scientists' publication productivity, peaking around age 45. As Kelchtermans and Veugelers (2013) recently summarized, cumulative advantage and learning predict increasing quality of research output (and increasing inequality in overall production) as one's "career age" increases. As such, the age quadratic employed in some studies thus may conflate both true aging-related effects, and effects of experience. To disentangle these, I specify career age (i.e., experience, defined as years elapsed since award of the PhD) and biological age as separate variables in the empirical models that follow.

Though Kelchtermans and Veugelers' (2013) paper focused specifically on publication output among academic faculty, there is a clear analogy for study of scientists' patenting and entrepreneurship. First, professional recognition and status attract rewards including research funding and access to better physical and human capital resources (e.g., laboratories, equipment, graduate students). The greater external recognition and reputation accruing to experience can thus be both the result of one's prior research productivity, and also serve indirectly to improve one's chances of future productivity. For academic faculty, professional rank may also reflect some aspect of the individual's productivity and research quality. Controlling for the specific STEM field and conditional on the individual's choosing to specialize in research and development activities, we would hypothesize individuals with higher levels of experience and seniority would thus have higher propensity to develop and participate in commercialization of inventions.

Second, at least among academic faculty, seniority is generally positively correlated with participation in a variety of commercially-oriented activities, including (but not limited to) faculty participation in industry-sponsored or –contracted research, consulting, patenting, licensing and commercialization (Perkmann, et al., 2013). One possible explanation for this greater industry engagement among those with greater experience is that, along with increased status and professional recognition, senior researchers have also had more time to grow broad professional networks—i.e., greater social capital (Aldridge, et al., 2014)—potentially affording them a greater range of opportunities for interaction and collaboration. As noted above and shown in Table 1, in our sample, male STEM PhDs had significantly higher average years of experience (11.9 versus 11.1 years). Furthermore, among STEM PhDs working in academia, over 13% of men were tenured, versus only 8% of women. Interestingly, with the possible exception of non-tenure-track academic employees, recent evidence suggests tenure and academic rank have no significant impact on entrepreneurial ventures.

Occupation and Work Activities.—The effect of increasing experience on innovation and entrepreneurship may also be mediated by one's occupation and primary work activities. As shown in Table 1, almost half (47%) of female STEM PhDs in our sample work in academia, versus just 37% of male STEM PhDs. Some of this difference is simply attributable to differences in the distribution, by gender, across STEM degree fields. Engineering PhDs, in particular, are substantially less likely than other STEM PhDs to work in academia. In addition, academic faculty with higher teaching loads are expected to have lower research output, and female STEM PhDs appear preferentially to select into academia, and into teaching-focused positions (Xie & Shauman, 1998). However, as Whittington (2011) discusses, the routes to and incentives for patenting strongly differ in academic versus industrial sectors. So, even among STEM PhDs who participate in licensing or commercializing an invention, academic faculty may have different rates of entry than non-academics into entrepreneurship, overall.

Descriptively, in this sample we do observe substantially lower rates of patenting, licensing and commercialization among STEM PhDs in academia versus in industry. In addition, among those who changed jobs between 2008 and 2010, less than 7% of those who became small business owners or employees of start-up ventures came from academia, whereas over three-quarters of new entrepreneurs previously worked in industry.[2] Based on these observations, I evaluate relevance of occupational variables including whether the individual was

[2] Perhaps consistent with the notion that one's talents and abilities reveal themselves over time, I also observe the most common reason cited by former-academic entrepreneurs for their job change was a "change in career or professional interests," mentioned by 68% of men and 50% of women leaving academia.

employed in academia as of 2008, whether his or her primary or secondary work activity (that is, the two most common work activities engaged in, in a typical week) was R&D, and finally how closely they feel their work relates to their doctoral field of degree.

Boundary-Spanning, Institutions, and Training Environments.—Next, motivated by Bercovitz and Feldman's (2008) study of medical scientists discussed above, I investigate possible imprinting due to greater commercial or applied focus in individuals' graduate training environments. As described in the Data section, above, I include three different measures: (a) the total volume of R&D and (b) the relative share R&D funded by industry and other non-federal sources in the student's field at his or her university, in the year he or she earned the PhD; and (c) the average number of university-assigned patents produced by members of the individual's doctoral institution over the five years preceding his or her degree completion, relative to other institutions that awarded PhDs to students in the same field.

In addition to graduate training effects, I also consider possible effects of PhDs' pre- or post-doctoral boundary-spanning activities. Prior entrepreneurship literature, especially that focused on academic entrepreneurs, has discussed the importance of boundary-spanning individuals for successful commercialization of academic scientists' research. I hypothesized that multidisciplinary training may also serve as a type of boundary-spanning, providing scientists with a broader experience set to draw on for recognizing commercially-relevant opportunities. More commonly recognized boundary-spanning training experiences could include taking postdoctoral employment with industry as discussed in the Data section above, or earning a master's degree in business administration or management.

For example, Greene et al. (2001) found that owners of high-growth entrepreneurial firms are more likely than other entrepreneurs to hold graduate degrees, and those who attract financing more often have engineering or business degrees. I therefore include a dummy variable that takes on value 1 if the respondent completed a subsequent (postdoctoral) degree in business or management, including but not restricted to MBA degrees. In addition, considering the possibility that multidisciplinary training early in one's career might conceivably also influence an individual's capacity for boundary-spanning and opportunity recognition,[3] I include an additional dummy variable for whether the respondent's bachelor's degree was earned in the same field or discipline as their doctorate.

Marriage and Parenthood. Finally, recent evidence has once again shown that family/household structure and especially parenthood can have very different impacts on female versus male scientists' research productivity (Whittington, 2011). I investigate the salience of these issues in the 2008 and 2010 SDR data, recoding variables for whether the respondent reports he or she is married or "living as married," and if so, whether the respondent's spouse or partner works full-time, and finally if so, whether the spouse or partner works in an occupation that requires at least a bachelor's degree in a STEM field. I also considered and tested several alternative approaches to capture how childbearing and presence of dependent children of different age ranges in the home might differentially impact male and female scientists.

For these family-related variables, as with many other variables considered but ultimately excluded from the final models presented here, model selection was guided both by theory and by empirical evidence presented across the multiple

[3] Lazear's (2005) work suggests an alternative conception and motivation for including possible effects of multidisciplinary education, namely that greater breadth in one's curriculum may signify a generalist or "jack-of-all-trades."

streams of literature on which we draw, as well as by data limitations and related empirical considerations. In general, model selection employed Akaike's Information Criterion to evaluate the merits of expanding each model, and where multiple measures were available to represent a given concept, I preferentially selected those for which provide most insight specifically into gender-related differences in entrepreneurship.

III. Results

What Explains the Gender Gap in STEM PhDs' Patenting?

To understand the relative contribution of various causes to the 13.2% gender gap in patenting across STEM fields, similar to Hunt et al. (2013) I estimated a series of models, each of them incrementally controlling for an additional set of potential explanatory variables. However, rather than linear probability models as Hunt et al. (2013) employed, I instead follow a nonlinear decomposition approach comparable to Fairlie's (1999). Results from this decomposition are reported in Table 2.

TABLE 2. DECOMPOSING THE GENDER GAP IN PATENTING AMONG STEM PHDS

Female	-0.132	-0.0938	-0.0657	-0.0655	-0.0637	-0.0606	-0.0579
Delta-method S.E.s	(0.0118)	(0.0133)	(0.0135)	(0.0136)	(0.0133)	(0.0133)	(0.0135)
PhD Field		X	X	X	X	X	X
Occupation, Sector & Work Activities			X	X	X	X	X
Race/Ethnicity & Citizenship				X	X	X	X
Age, Experience, & Tenure Status					X	X	X
Training Environments						X	X
Parenthood							X
AIC	28.96	26.67	24.70	24.63	24.62	24.36	24.25

Gender decomposition following survey-weighted logistic regression estimation, on 2008 and 2010 Survey of Doctorate Recipients data and linked responses from Survey of Earned Doctorates, 1985-2003. Analytic dataset includes 6,107 respondents, each of whom earned a research doctorate in a STEM field from a U.S. institution between 1985 and 2003. Outcome variable equals 1 if the individual reports having been named as inventor on one or more patent applications between October 2003 and October 2008. Reported results for female gender are average marginal effects using pooled coefficients. Each model includes gender-specific constants, explanatory variables as noted above, as well as interactions of all explanatory variables with female gender.

As in Hunt et al.'s analysis of individuals with STEM bachelor's degrees, here I find approximately one-third of gender gap (27-34%) in STEM PhDs' patenting can be explained by differences in the gender distribution across STEM PhD fields.

I estimate that another one-fifth of the gender gap in STEM PhDs' patenting can be attributed to differences in male and female STEM PhDs' occupations, including whether they are employed in academia (which is associated with lower rates of patenting than other sectors), whether their primary or secondary work activity is R&D (basic research, applied research, development, or design), and whether their job is closely related to their doctoral field of degree. Combined with gender differences in PhD completions across STEM fields, these gender differences in occupational activities and employment sector (academic or otherwise) explain about half of the patenting gender gap.

Adding controls for race/ethnicity and citizenship status provided little additional explanatory power, in part because there does not seem to be systematic correlation between our outcomes of interest, key explanatory variable (gender) and these other demographic characteristics. That is, although these additional demographic characteristics are useful predictors in that they help to reduce the residual unexplained variance across individuals' outcomes in our data, these characteristics explain very little of the gender gap, itself. Results suggest that less than 1% of the patenting gender gap is attributable to differences in the share of women among U.S. citizens, permanent residents, foreign temporary residents, and underrepresented racial and ethnic U.S. minorities.

Gender differences in experience and seniority (including prior tenure, among academic faculty) explain very little of the remaining gap in patenting, overall. Moreover, if we assume graduate and postdoctoral training experiences should have the same impact for both male and female STEM PhDs, then—after controlling for field and occupation—it appears only about 2% of the overall gender patenting gap is attributable to these differences, as well. Finally, having a child under age 6 at home during the patenting lookback period likewise appears to explain about 2% of the overall gender gap in patenting among STEM PhDs.

Taken together, the variables considered seem to explain well over half (56%) of the gender gap in STEM PhDs' patenting. However, certain of these training environment variables have significantly different impacts for men versus women. Table 3 presents estimation results for the full, survey-weighted logistic regression model, with marginal effects on probability of having filed a patent as inventor in the past five years modeled separately by gender. In addition to the variables previously described, the full model also permits interactions between the indicator for R&D work activity and the categorical variable for how close one's occupation is to his or her field of degree. The final column indicates whether the difference in the margin estimates for men and women are statistically significant across the two models, at $p<.10$.

TABLE 3. DEMOGRAPHIC, INSTITUTIONAL, AND OCCUPATIONAL PREDICTORS OF STEM PHDS' PATENTING

	Women		Men		Significant Difference?
Racial/ethnic minority	-0.0180		-0.0780	***	**
Foreign-born	0.0345	*	0.0314	**	
Research-intensive occupation	0.1408	***	0.1750	***	
Occupation "closely related" to PhD field	0.0651	***	0.0301	**	
Academic employment, untenured	-0.1048	***	-0.1626	***	**
Academic employment, tenured	-0.1033	***	-0.1623	***	**
Years since PhD awarded	0.0089	***	0.0129	***	**
Age/10, squared	-0.0075	***	-0.0117	***	**
Married	-0.0339		0.0274		*
Child under age 6	-0.0454	**	-0.0144		
Earned MBA or similar degree after PhD	0.1135		-0.0135		*
Industry-funded postdoctoral employment	0.1066	***	0.0771	***	**
Bachelor's degree in same field as PhD	0.0053		-0.0074		
PhD Institution Characteristics:					
Total R&D in PhD field (Log $K)	0.0155		0.0372	***	*
Non-federal R&D in PhD field (Log $K)	-0.0101		-0.0249	**	
Patents, 5-Yr Average (divided by 10)	0.0025	**	0.0006		
Number of Observations	1,945		4,162		6,107
Number of Universities	198		217		226

*** p < .01 ** p < .05 *p <. 10

Average marginal effects for changes in probability of a STEM PhD having filed at least one patent as inventor in the five-year period October 2003-October 2008, conditional on labor force participation in 2010. Results from subpopulation survey-weighted logistic regression. PhD field-specific constants also included (not shown). Post-estimation marginal effects calculated separately over gender.

Data sources: Survey of Doctorate Recipients (SDR) 2008 & 2010; Survey of Earned Doctorates – Doctorate Records File, 1990-2003; Survey of R&D Expenditures at Universities and Colleges, 1985-2003; U.S. Patent and Trademark Office (USPTO) records for patents granted 1985-2012.

Among male STEM PhDs, historically underrepresented racial and ethnic minorities have nearly 8 percentage points lower probability of having filed a patent, as compared with non-minority, native-born U.S. citizens. However, we see no evidence of a double-bind for minority women in STEM: the marginal effect of minority status is not statistically significant in the women-only model, and the estimated effect of minority status for women is significantly lower than that for men ($p<.05$). On the other hand, consistent with prior research, we find that foreign-born scientists and engineers are significantly more likely than native U.S. citizens to have patented (Hunt, 2011; Kerr, 2013; Kerr & Lincoln, 2010).

Working in a research-intensive occupation—that is, working in an occupation where one's primary or secondary work activity in a typical week is basic research, applied research, development, or design—is the most influential predictor of patenting, with no significant difference in the effect of such occupations by gender. Working in an occupation "closely related" to one's PhD field further increases probability of patenting. Including interaction terms for relatedness—not related, somewhat related, or closely related—and research intensity, we find a statistically insignificant 5 percentage point difference in predicted probabilities of patenting among men and women in research-intensive occupations closely related to their PhDs.

As previously noted, STEM PhDs in academia patent at much lower rates than their counterparts in industry: 16 percentage points lower probability for men, and 10 percentage points lower probability for women. However, after separately controlling for both experience (years since PhD) and aging effects (age/10, squared), we find no effect of academics' tenure status on their probability of recent patent filing. On the other hand, we do find probability of patenting increases with experience and declines with age, but at significantly different rates for men than for women. Men’s probability of patenting increases more rapidly with experience than women’s, but also falls much more rapidly with age.

For men, probability of subsequent patenting increased if they attended a PhD program that conducted relatively higher total R&D volume, but especially if their graduate program relied on federal sources for a greater share of its R&D expenditures. The estimated effect of attending a program with higher total R&D volume was significantly lower for women than for men, with no relationship apparent between dominant R&D funding source and women’s subsequent patenting. So what did matter for women?

First, women who earned a master’s in a business-related field (i.e., MBA or similar) after their PhDs were just as likely as men (with or without a MBA or similar training) to have filed a patent application within the past five years. Female STEM PhDs’ probability of patenting increased by over 60% with a postdoctoral MBA or similar degree (p=.12), whereas for male STEM PhDs, earning a subsequent business degree had essentially zero impact.

Second, although for men postdoctoral employment in industry was associated with a 7.8 percentage point increase in probability of patenting (p<.01), the magnitude of the effect for women was substantially and significantly higher, increasing their probability of patenting by 10.7 percentage points. In effect, for female STEM PhDs, either: (a) completion of a MBA or similar degree after their PhD, or (b) having their first postdoctoral employment “paid for” by industry—either of these seems sufficient to close the remainder of the gender gap in patenting.

Finally, though their doctoral university’s relative patenting volume had essentially no added impact on male STEM PhDs’ subsequent patents, for women this aspect of the graduate training environment again proved highly significant. Attending a doctoral program at a university at the 75th percentile for patenting versus at the 25th percentile increased the probability of a female STEM PhD filing a patent by about one percentage point.

In contrast with Whittington's (2011) earlier study that used data from the 1995 and 2001 SDR waves, in the 2008 SDR we find significant evidence that recent parenthood affects women scientists' patenting rates differently from men's, and not just among male and female scientists employed in academia. For men, we find that having a young child at home appears to have no practical or statistically significant impact on their probability of filing at least one patent application during the look-back window. For women, however, having a young child at home is associated with a 4.5 percentage point decrease in the probability of filing a patent. Put another way, after controlling for all the other variables we discuss above, and conditional on women not having a young child at home, the gender gap in patenting is sufficiently small as to be no longer statistically significant.

One possible reason for this difference in our results is due to coding of the relevant explanatory variable. Whittington (2011) argues that "parental responsibilities for children of all ages can cause work/family conflict," so uses presence of any dependent children under 18 at home as the explanatory variable. By contrast, our "parenthood" indicator variable takes on value 1 for presence of a child under six years of age in the respondent's home in 2008, which corresponds to a child born either during or just prior to the five-year look-back period, over which the respondent reports his or her patenting behavior.[4] Sensitivity tests including additional categorical variables for older age groups found no statistical evidence of impact, for men or women.

[4] Though we cannot rule out the possibility that an older child might have joined the household in 2008 by some means (blended households, adoption, and so on), nor that a young child might have been present during the period 2003-2008 but is no longer living in the respondent's home in 2008, we have no reason to expect that measurement error in either direction would be systematically correlated with patents production.

In the full, final model, comparing field-specific fixed effects from the "male" model with those from the "female" model reveals only two fields with persistent, significant, and as-yet-unexplained gender gaps in STEM PhDs' patenting rates.[5] In chemistry, there is still a 19-percentage-point gap, with female PhDs patenting at about half the rate of male PhDs, all else equal. Similarly, in medical sciences, there is a 12-percentage-point gap, with female PhDs patenting at about 65% of male PhDs' rate, all else equal.

What Explains the Gender Gap in STEM PhDs' Entrepreneurship?

In this final section, I take a similar modeling approach as for STEM PhDs' patenting, above, to describe the relative contributions of various potential influences to the gender gap in male and female STEM PhD's participation in entrepreneurial ventures.

I begin by defining entrepreneurship broadly, as noted above, to include: (a) unincorporated, non-employer self-employment; (b) incorporated self-employment or small business ownership; or (c) employment with a new venture that was founded within the past five years, and that has fewer than 100 employees.

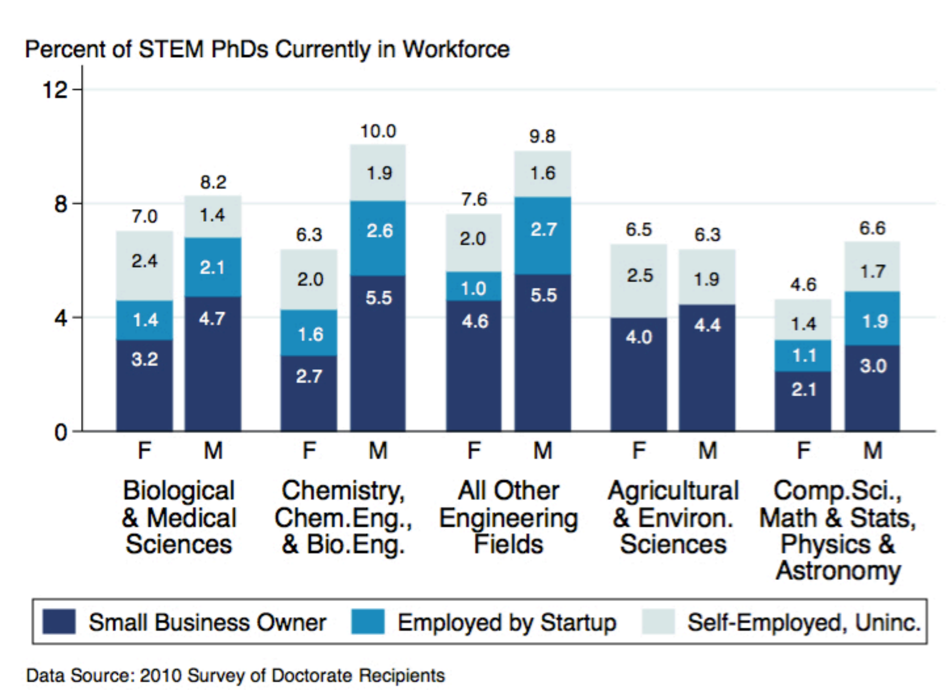
With this broad definition, I estimate 7.0% of male STEM PhDs and 5.4% of female STEM PhDs participate in entrepreneurship, resulting in a gender gap of 1.6 percentage points (p=.008). From an economic and policy perspective, non-employer self-employed individuals are less likely to contribute substantially to the science-based, innovative economic growth that we seek. At the same time, among both recent and more senior STEM PhDs, women are significantly less likely than men to own small businesses or join start-up companies. If we exclude

[5] Results robust to Bonferroni correction for multiple comparisons.

unincorporated self-employment, then among STEM PhDs who graduated 2006 or earlier and who were in the workforce in 2010, the gender gap widens slightly, to a highly significant 1.71% ($p<.001$).

There also exist very dramatic differences across STEM fields in women's participation in entrepreneurship, relative to men's. For example, in Figure 1 below, if we add together individuals who are self-employed unincorporated, and those who are small business owners (and these are the individuals more commonly labeled as entrepreneurs in most studies), we find that 6.6% of female engineers and 7.1% of male engineers engage in entrepreneurship. The entrepreneurial venturing gap widens, however, across all fields, when we also include STEM PhDs who join startup ventures as employees.

Figure 1. Entrepreneurial Venturing by Gender and PhD Field



As in the previous section's patents analysis, here I use a series of logistic regressions to perform nonlinear decomposition, beginning with PhD field.

Results for this decomposition are presented in Table 4. In contrast with the earlier findings for patenting, for entrepreneurship we see less than one-quarter (10-22%) of the gender gap is explained by differences in the gender distribution across PhD fields.

TABLE 4. DECOMPOSING THE GENDER GAP IN STEM PHDS' ENTREPRENEURIAL VENTURING

Female	-0.0161	-0.0138	-0.00637	-0.00546	-0.00513
Delta-method S.E.s	(0.00581)	(0.00650)	(0.00691)	(0.00688)	(0.00690)
p-value:	< .01	.033	0.43	0.33	0.46
PhD Field		X	X	X	X
Race/Ethnicity & Citizenship			X	X	X
Occupation & Experience			X	X	X
Training Environments				X	X
Parenthood					X
AIC	12.17	12.01	10.81	10.76	10.73

Gender decomposition following logistic regression estimation, using 2008 and 2010 Survey of Doctorate Recipients data and linked responses from Survey of Earned Doctorates, 1990-2006. Analytic dataset includes 8,829 respondents, each of whom earned a research doctorate in a STEM field from a U.S. institution awarded between 1990 and 2006, inclusive. Outcome variable equals 1 if the individual reported in 2010 that they were self-employed (including unincorporated self-employed), owner of a small business with fewer than 500 employees, or employed by a new business founded in the past five years with fewer than 100 employees.

Reported results are average marginal effects using pooled coefficients. Each model includes gender-specific constants, explanatory variables as noted above, as well as interactions of all explanatory variables with female gender.

Due to employment restrictions that affect foreign workers' ability to participate in entrepreneurship, I next added the set of citizenship and race/ethnicity control variables. However, none of these made a difference with respect to the gender gap in entrepreneurship (result column omitted for brevity).

I next controlled for years of experience, prior academic employment, and prior patenting experience. Patenting experience measures included both the patent filings outcome variable from the previous decomposition, as well as an additional indicator variable representing whether the individual reported having commercialized or licensed a patent over that same five-year period.

After field-of-degree, occupational sector, and graduate school training environment variables are controlled for, male STEM PhDs' industry-sponsored postdoctoral employment and more recent patenting experience have no significant influence on their participation in subsequent entrepreneurial ventures. But for women, entrepreneurship—even conditional on prior patenting—is significantly more common among those who had industry-supported postdoctoral employment.[6] For this subset of women, the predicted probability of participating in entrepreneurship is not significantly different from that for men.

Relative to male STEM PhDs, female STEM PhDs have significantly higher rates of entrepreneurship if they attended graduate programs with higher levels of non-federal R&D funding, or in a university with higher overall patents production. Together with the other variables described above, these variables explain 34 to 48% of the gender gap in STEM fields entrepreneurship.

[6] The significant, positive difference in the impact of industry employment for female versus male scientists recalls Lin and Bozeman's (2006) similar positive result for female—but not male—academic scientists who had prior industry experience.

TABLE 5. DEMOGRAPHIC, INSTITUTIONAL, AND OCCUPATIONAL PREDICTORS OF STEM PHDS' PARTICIPATION IN ENTREPRENEURIAL VENTURES

	Women		Men		Sig. Diff.?
Racial/ethnic minority	-0.0026		-0.0034		
Foreign, temporary resident	-0.0249	**	-0.0328	**	
Has child under age 2	-0.0456	***	-0.0038		**
Married	0.0125		0.0066		
Filed one or more patents, 2003-2008	-0.0202	**	0.0047		*
Held academic job in 2008	-0.0842	***	-0.0970	***	
Years since PhD awarded	0.0030	***	0.0025	***	
Earned MBA after PhD	0.0180		-0.0140		
Industry-funded postdoctoral employment	0.0306	**	0.0013		*
Bachelor's in same field as PhD	-0.0081		-0.0033		
Educational debt at graduation > $30K	0.0403	*	-0.0089		**
PhD Institution:					
Total R&D in PhD field (Log $K)	-0.0195	**	0.0136	**	**
Non-federal R&D in PhD field (Log $K)	0.0172	*	-0.0090	*	*
Patents, 5-Yr Average	0.0007		-0.0006		
Private Control	0.0157		0.0100		
Number of Observations	8,829				
Number of Universities	260				

*** p < .01 ** p < .05 *p <. 10

Average marginal effects for changes in probability of a STEM PhD engaging in entrepreneurship, conditional on current labor force participation. PhD field-specific constants also included (not shown). Post-estimation marginal effects calculated separately over gender.

Data sources: Survey of Doctorate Recipients (SDR) 2008 & 2010; Survey of Earned Doctorates – Doctorate Records File, 1990-2006; Survey of R&D Expenditures at Universities and Colleges, 1985-2006; U.S. Patent and Trademark Office (USPTO) records for patents awarded 1985-2012.

Table 5 presents results from the full logistic regression model, with average marginal effects of each explanatory variable on the predicted probability of STEM PhDs' engaging in entrepreneurship estimated separately for men and women, via inclusion of an indicator variable for female gender as well as interactions between female gender and all explanatory variables shown.

We observe no statistically significant difference in STEM entrepreneurship for racial or ethnic minorities versus non-minority U.S. citizens or permanent residents. However, as expected given employment restrictions for foreign temporary residents, their participation in entrepreneurship is significantly lower for both men and women, albeit with no significant difference by gender.

Intriguingly, although the pooled coefficient suggests gender differences in patenting and commercialization have no influence on subsequent entrepreneurship, this camouflages significantly different results obtained in the gender-specific regressions. There, we find women who have experience commercializing or licensing a patent are significantly less likely to engage in subsequent entrepreneurship, whereas men with the same experience appear more likely to engage in entrepreneurship.[7]

These gender differences in the effects of prior patents' licensing or commercialization might be correlated with gender differences in sector of employment. For example, chemical engineering and electrical engineering lead all other fields in PhDs' licensing and commercialization of patented inventions. But, in these fields, female PhDs are also significantly more likely than male PhDs to be employed in academia. Additional models (not shown) interacting

[7] The marginal effects for male versus female STEM PhDs of having filed a patent in the five-year reference period on predicted probability of entrepreneurship are statistically significantly different from each other at the 10% level. However, for men, as shown in Table 4 we cannot rule out zero effect of patent filing on subsequent entrepreneurship. By contrast, the alternative licensing and commercialization measure described here does result in a statistically significant, positive estimate for men.

prior employment sector with prior patenting experience reveal a more nuanced finding: relative to all other STEM PhDs working outside of academia, females who work outside of academia and who recently licensed or commercialized a patented invention are *less* likely to become entrepreneurs, whereas males with those same characteristics are *more* likely to become entrepreneurs.

As noted above, having a young child makes a substantial difference for women's participation in entrepreneurship. Female STEM PhDs with any child under age 2 at home have 4.6 percentage points lower probability of engaging in entrepreneurship of any kind, including unincorporated self-employment, compared to other female STEM PhDs. For male STEM PhDs, the corresponding point estimate is 0.4 percentage points, and is not statistically significant.

Prior patenting also has significantly different effects for men and women. In this model, I use the indicator for having filed any patents, to maintain consistency with the outcome variable in the patenting regressions reported earlier. As discussed in the decomposition analysis above, if we instead use the indicator variable for patents commercialization and licensing, we obtain very similar results.

For both men and women, employment in the academic sector as of 2008 significantly and substantially decreases likelihood of moving into entrepreneurship, all else equal. Likewise, for both genders, increasing experience—as measured by years since PhD was awarded—is associated with higher rates of entrepreneurship.

The influences of R&D funding in the graduate training environment also differ significantly for men versus women. For men, their graduate institution's total volume of R&D in their field is a strong positive predictor, whereas for women, it is specifically the amount of R&D funded by industry and non-federal sources, and its *share* of the total. The negative sign on total R&D coupled with the positive sign on non-federal R&D indicate the latter: an increase in total R&D due to an increase in federal R&D funding (holding non-federal R&D constant) significantly decreases women's propensity towards entrepreneurship, whereas an increase in non-federal R&D funding holding total R&D constant (i.e., increasing the non-federal share) significantly increases women's propensity towards entrepreneurship.

Having their first postdoctoral employment in industry, or with funding from industry sources, also significantly increases women's probability of subsequent entrepreneurship, by 3.1 percentage points. But for men, the point estimate is again insignificant, only 0.1 percentage points. We also observe a positive sign for women's earning a MBA or similar degree after their PhD—a significant predictor of women's patenting in the previous regression set—but with only 30 female STEM PhDs in our sample holding these degrees, this result was imprecisely estimated and not statistically significant. Finally, though we see negative signs for the estimated effects of earning one's PhD in the same field as the bachelor's degree, consistent with our intuition that multidisciplinary academic training may increase propensity towards entrepreneurship, these estimated effects are also not statistically significant.

Finally, female STEM PhDs with over $30,000 in cumulative higher education debt at the time they complete their PhDs have 4.0 percentage points higher probability of entrepreneurship, as compared with those with less cumulative debt. It is important to note, this debt measure does not reflect debt load currently remaining, which would have potential to individuals' personal access to credit. In fact, when I included additional terms in the model to allow these debt loads to decay over time—that is, so that student debt would have progressively less influence as years since graduation increased—these terms were not significant, and did not improve model fit (per the Akaike Information Criterion). There are several possible explanations for this finding. For example, one might expect debt-aversion to be negatively correlated with entrepreneurial venturing, especially for high-tech ventures requiring substantial upfront investment. Women who demonstrate willingness to take on significant debt as students might thus be understood as less debt-averse (and possibly less risk-averse) than their same-field, same-gender peers.

IV. Conclusions

Women-owned businesses (WOBs) have typically and historically lagged behind male-owned businesses on a variety of traditional economic performance measures, including their use of external financial capital, growth in revenues and income (Brush, Carter, Gatewood, Greene, & Hart, 2003; Morris, Miyasaki, Watters, & Coombes, 2006). Some studies have also attributed WOBs' lower overall capitalization and slower growth in revenues and employment to structural and sectoral differences in the industries women entrepreneurs choose to enter (Carter & Allen, 1997; Watson, 2003). To the extent that STEM field-specific human capital constrains the industries entrepreneurs can profitably enter, women's underrepresentation in STEM degree programs will continue to be a limiting factor in their entrepreneurial venturing. However, even among men and women who earn PhDs in the same STEM field, I find there still remain substantial differences in rates of innovation and entrepreneurship, by gender. Approximately half of these differences are due to employment sector and occupational activities, as female STEM PhDs more often take jobs in academia, and less often hold research-focused occupations.

Interestingly, women who licensed or commercialized a patent over the period October 2003 through October 2008 were significantly *less* likely to become entrepreneurs than women who did not have that previous commercialization and licensing experience, controlling for field of degree, prior employment sector, age and years since PhD, family/household characteristics, and several other demographic factors. If the effect for men were simply positive, with a lesser or insignificant effect observed for women, one might posit—similar to Gicheva & Link (2013)—that nascent female scientist-entrepreneurs have more difficulty attracting private investment for the technology's development, so may be less likely to participate in commercial development themselves as business owners.

But in this case, it seems instead that women scientists and engineers who are productive in innovative, commercially-relevant research are substantially more likely to be (and remain) employees of large, established firms.

For male STEM PhDs, training in graduate programs with relatively higher overall research intensity (as measured by total R&D expenditures in their field) is a positive predictor of subsequent entrepreneurial ventures. This result is not inconsistent with conclusions from several prior studies that found, at the individual level, traditional research outputs like publications are complementary to patenting (Agrawal & Henderson, 2002; Goldfarb, Marschke, & Smith, 2009; Gulbrandsen & Smeby, 2005).

The more remarkable result, however, is the finding that graduate and postdoctoral training environments matter, and they matter differently for men versus women scientists and engineers. After controlling for their field-of-degree, sector and occupational characteristics, years of experience, and transient parenthood effects, we still find substantial variation by gender both in patenting and in entrepreneurial venturing that appears to be due to differences in PhDs' graduate and postdoctoral training environments. In principle, one could argue the correlations we observe between graduate program characteristics and PhDs' outcomes are due to selection bias: prospective graduate students with innate capability and commercial orientation may simply choose to attend programs with greater private sector R&D funding, within institutions that have higher overall patenting volume. This argument would likely be persuasive, were it not for the highly significant differences we observe by gender.

For men, subsequent rates of patenting and entrepreneurship are highest among those who attended the largest, most research-intensive graduate programs in their field, with a relatively high proportion of R&D funding from federal sources. By contrast, holding total R&D expenditures constant, attending a university with higher patenting output has no effect on men's subsequent patenting, and graduating from a program with a higher share of R&D funded by industry and other non-federal sources has no effect on men's subsequent entrepreneurship.

For women, however, we see a small, positive and significant effect of attending a university with higher patenting volume, but a much larger positive effect on entrepreneurship among those who attended graduate programs with a higher share of R&D funded by industry or other non-federal sources. Similarly, though having one's first postdoctoral employment in industry, or with funding from industry sources, significantly increases probability of subsequent patenting for both men and women, the effect for women is markedly higher. Moreover, whereas for women an industry postdoc significantly increases their probability of subsequent entrepreneurship, for men that has no effect. Finally, whereas for women earning a MBA or equivalent after the PhD appears to support subsequent patent filing, for men this is not the case. Taken together, these findings seem to suggest that exposure to commercially-oriented R&D in graduate school and postdoctoral training may help to address highly-educated women's relatively greater self-perceived lack of competency vis-à-vis entrepreneurship (Shinnar, Giacomin, & Janssen, 2012).

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