Gender, Education, and Occupation: How Founder Experiences Influence Firm Outcomes

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ABSTRACT

This study analyzes the gender, education and occupational backgrounds of high-technology firm founders and the outcomes of their firms by asking three main questions: 1) What are the backgrounds of women entrepreneurs of technology firms? 2) Do female founders of technology firms have similar educational and occupational backgrounds as male founders? 3) What is the relationship of a high technology entrepreneur's gender, educational and occupational backgrounds, and firm outcomes? Exploring these questions furthers our understanding of how high-technology founders' experiences influence their firms' outcomes taking into consideration gender. The data show the variety of career paths that lead to women starting technology firms. The study discovers that female and male high-technology entrepreneurs have very similar education and occupational backgrounds. However, the backgrounds of founders play a significant role in the likelihood that their firms suffer a negative closure, is acquired, or obtains venture capital, but in different ways depending on gender. These results confirm the importance of examining heterogeneity in women entrepreneurs' background. Moreover, the study highlights that similar types of human capital can be regarded and experienced differently. Implications for science and innovation policy are discussed.

Keywords: entrepreneurship, gender, founding teams, backgrounds, acquisition, venture capital

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Academic literature and popular press often lament the dearth of women in technology fields, especially in start-ups. Less than five percent of new high technology firms are started by women in Europe and the United States (Cohoon, Wadhwa, & Mitchell, 2010; European Commission, 2008; Wadhwa, 2012), compared to about 30 to 40 percent of all firms (European Commission, 2014; Morelix, Fairlie, & Tareque, 2017). As high technology entrepreneurship is a critical driver of a country's economic health, employment, productivity growth, and technological advancement (Hathaway, 2013), women entrepreneurs remain an overlooked resource for innovation and economic growth. Consequently, policy makers and organizations around the world have created initiatives to support women in high technology careers, particularly entrepreneurship (e.g., U.N. Women Innovation and Technology, Girls in Tech, Million Women Mentors, Girls Who Code, ASTIA).[1] Previous work has examined why so few women start technology firms and identified supply (e.g., individual characteristics and human capital) and demand (e.g., discrimination and exclusion) concerns that hinder female participation (e.g., Ding, Murray, & Stuart, 2006; Fuentes-Fuentes, Cooper, & Bojica, 2012; Stephan & El-Ganainy, 2007). While we know why few women start high technology firms, we know little about the educational backgrounds and careers of those women who do start these firms and how their backgrounds influence their firms' trajectories. Given the magnitude of resources being directed toward supporting females in technology entrepreneurship around the world, a better comprehension of the backgrounds, career paths, and trends of women who

[1] See UN Women Innovation and Technology: www.unwomen.org/en/how-we-work/innovation-and-technology; Girls in Tech: girlsintech.org; Million Women Mentors: www.millionwomenmentors.org; Girls Who Code: girlswhocode.com; and ASTIA: astia.org

launch successful high technology companies is needed. Thus, this study turns the lens to examine those who create high technology firms instead of those who don't.

Another critical component of understanding how to support the development of women entrepreneurs is to determine how technology firms created by women perform and if this differs from those led by men. Unfortunately, work on how female-led firms perform more generally has yielded inconsistent and conflicting results, depending on the methods used, measures employed, and contexts in which the studies were conducted (Jennings & Brush, 2013; Kalnins & Williams, 2014). Therefore, the relationship between founder gender and firm performance remains unclear. This puzzle remains, in part, due to the treatment of women as homogeneous, which is remarkable given the amount of work looking at the variety of founders' human capital more broadly (e.g., Davidsson & Honig, 2003; Gimeno, Folta, Cooper, & Woo, 1997). Indeed, the heterogeneity of women founders in *high technology* and the performance of their firms has been neglected in research (Blume-Kohout, 2014; Wynarczyk & Renner, 2006). Furthermore, while human capital theory argues that education and work experience influence the ability of founders to obtain resources, it does not adequately address how similar types of human capital can be regarded and experienced differently depending on gender. Congruity and other theories do not explain how women succeed in a role for which they are incongruent in terms of sector (technology being considered masculine, see Marlow & McAdams, 2012) and occupation (entrepreneurship being considered masculine, see Ahl, 2006; Stephan & El-Ganainy, 2007). Consequently, knowledge about women high technology entrepreneurs, their backgrounds and the outcomes of their firms does not match that regarding male entrepreneurs (de Bruin, Brush, & Welter, 2007; Jennings & Brush, 2013).

The goal of this study is to empirically explore some of the unresolved questions about which women become technology entrepreneurs and how the heterogeneity of entrepreneurs' backgrounds influences the outcomes of their firms. In addition to providing detailed data regarding the state of women entrepreneurs in technology, this study asks three main questions: 1) What are the backgrounds of women entrepreneurs of technology firms? 2) Do female founders of technology firms have similar educational and occupational backgrounds to male founders? 3) What is the relationship of a high technology entrepreneur's gender, educational and occupational backgrounds, and firm outcomes? Exploring these questions furthers our understanding by examining how the diversity in the experiences of female technology entrepreneurs influence their firms' outcomes (Hughes & Jennings, 2012; Jennings & Brush, 2013). Using a database of all nanotechnology firms started before 2011, this study is able to examine entrepreneurship across industries, but within a related field. The database compiles and matches 30 years of longitudinal firm-level data from several sources to provide a rich view of the field. As such, the data provide empirical insight into the diversity of technology founders' education and career trajectories. Hence, the study contributes advancing current discourse on gender, entrepreneurship, and organizational-level theory building (Joshi, Neely, Emrich, Griffiths, & George, 2015).

The study shows that female and male high technology entrepreneurs have very similar education and occupational backgrounds. However, women and men with similar backgrounds obtain different outcomes for their firms, a finding that confirms the need for additional work concerning how men and women experience analogous circumstances differently. For example, in contrast with previous work that suggests that universities are not supportive environments for female academic entrepreneurship (e.g., Ding & Choi, 2011; Murray & Graham, 2007; Rosa &

Dawson, 2006; Stephan & El-Ganainy, 2007), the findings show the percentage of founders with academic backgrounds is the same for women and men. However, women are more likely to have previous careers as research scientists than men, which raises questions about the *career specific* norms, perceptions and motivations that support or deter entrepreneurship. Heterogeneity in terms of founders' gender, education, and occupational background provide different human capital, experiences and resources for a nascent firm, which are not independent of the contextual pressures and motivations that shape an entrepreneur's actions. Research on this interdependence provides more granular insights into how a founder's background influences the development of the firm. Thus, this study contributes to the understanding of entrepreneurial microfoundations by being one of the first to explore the relationship between gender, educational and occupational backgrounds, and firm outcomes in high technology sectors. Additionally, the findings provide support for improving science and innovation policy by establishing a set of facts regarding women in technology entrepreneurship.

BACKGROUND

The percentage of firms started by women has increased over time, but female entrepreneurs remain underrepresented in technology fields. As mentioned, women start about 30 percent of new businesses in Europe and about 40 percent of those in the U.S. (European Commission, 2014; Morelix et al., 2017). However, only about five percent of European and about three percent of American high technology firms are founded by women (Cohoon et al., 2010; European Commission, 2008; Wadhwa, 2012). Should the percentage of high technology firms founded by women match that in other sectors, the number of female technology entrepreneurs would increase ten-fold. Approximately 20,000 new technology firms are started in the U.S. annually (Haltiwanger, Hathaway, & Miranda, 2014; Hathaway, 2013), which would equate to about 7,000 more female entrepreneurs starting high technology firms each year.

While the stream of research on women's entrepreneurship has grown considerably, little work has examined women who found high technology firms (Jennings & Brush, 2013; Blume-Kohout, 2014). Resoundingly, work on women and entrepreneurship has yet to discover if the backgrounds of female and male founders of high technology firms differ or how differences, if any exist, affect firm performance (for reviews of the literature, see Jennings & Brush, 2013; Link & Strong, 2016; Sullivan & Meek, 2012). The following section reviews work on women's entrepreneurship most relevant to high technology ventures and founders' backgrounds.

Founder Education and Gender

Both male and female entrepreneurs tend to be better educated than non-entrepreneurs (Dolinsky, Caputo, Pasumarty, & Quazi, 1993) though it is not clear if there is any difference in the average education of female and male entrepreneurs. For instance, Cowling and Taylor (2001) find that female entrepreneurs tend to be more educated than male entrepreneurs in the U.K., while McGraw (1998) finds that male entrepreneurs have higher levels of post-secondary education than female entrepreneurs in Canada. Other studies find no relationship between education and self-employment (Blanchflower, 2004; Brush, 1992; Burke, FitzRoy, & Nolan, 2002). Indeed, Minniti and Nardone (2007) find that, "the relationships between the likelihood of starting a business and age, household income, work status, and education do not depend on gender" (2007: 235).

Founders of high technology firms tend to be well educated, many with degrees in STEM-(science, technology, engineering and math) fields (Wadhwa, Freeman, & Rissing, 2008).

Robb and colleagues (2014) find that, indeed, the primary owners of technology-based firms in the Kauffman Survey of businesses tended to be highly educated, with over two-thirds holding a college degree and almost a third achieving post-graduate education (compared to 12 percent of the general U.S. population[2]). Table 1 shows the percentage of doctoral degrees earned by women between 1988 and 2015 by field. Figure 1 further illustrates the total number of doctoral degrees in STEM fields awarded each year between 1981 and 2015, the number awarded to men and women, and the percentage of those earned by women (shaded). The table and figure show that the percentage of women earning STEM-related doctoral degrees has generally increased over time. In fact, the graduation rates of STEM doctoral programs in the U.S. have reached near parity, with the percentage of women graduates rising from 23 percent in 1981 to over 40 percent in 2015 (National Science Foundation, 2016). In Europe, women make up about 42 percent of science, math, and computing doctoral graduates and almost 30 percent of doctoral graduates in the fields of engineering, manufacturing, and construction (European Commission, 2016). One argument for the low number of women founders in high technology fields is the lack of supply since, historically, fewer women have earned doctoral degrees in STEM fields than men (Blume-Kohout, 2014). By reason of these trends, one would expect that the number and percentage of high technology firms founded by women with doctorates in STEM fields would also increase over time. However, the percentage of high technology firms founded by women remains at or below five percent (European Commission, 2008; Wadhwa, 2012).

Insert Figure 1 & Table 1 about here

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[2] Source: U.S. Census Bureau, 1994–2015 Current Population Survey www.census.gov/content/dam/Census/library/publications/2016/demo/p20-578.pdf

It would be rational to expect the percentage of women founders to remain the same if firm founding and doctoral graduation rates mirrored one another. However, the increase in the founding of high technology firms by women is less than half that of the growth in doctoral degrees earned by women each year. In the U.S., the number of high technology firms started each year increased from about 11,000 in 1980 to about 20,000 in 2012, or over 80 percent (Haltiwanger et al., 2014; Hathaway, 2013). During the same period, the number of STEM doctoral degrees awarded to men increased from about 18,000 to 35,000, a 94 percent increase, and those earned by women from 4,200 to over 14,300, a 240 percent increase (see Figure 1). Thus, the supply of women with technology-related doctoral degrees increased faster than the supply of men with similar degrees. It is intriguing that the near parity in STEM-related doctoral degrees has not translated into an increase in women starting STEM-related or high technology firms. It remains unclear whether or how policies to further improve gender parity in STEM doctoral programs influence the participation of women in creating high technology firms. We need to discover whether the educational backgrounds of high technology founders differ by gender to assess the meaning of the apparent disparity between STEM education and entrepreneurship in related fields.

Previous Occupations of Founders and Gender

The occupational history of entrepreneurs provides insight into how a person's career influences their likelihood of starting a firm, the type of firm created, and how prior experience shapes a founder's opportunity enactment. Few studies have compared the occupational backgrounds of entrepreneurs by gender, and the little work that exists offers conflicting findings. For example, Fairlie and Robb (2009) find that male and female business owners in the

U.S. have similar managerial experience and years of work experience, although women have fewer years of experience in businesses similar to their new venture. However, Boden Jr. and Nucci (2000) find that female sole-proprietors tend to have less managerial experience than male sole-proprietors. One reason for the conflicting results may be the differences in samples; sole-proprietors are a subset of business owners, which includes other forms of firm structures such as corporations and partnerships. This leads to confusion regarding the differences and similarities between men and women entrepreneurs with regards to their work experience.

Research focusing on entrepreneurs in high technology sectors has almost universally looked at the likelihood of starting a firm based on intellectual property (IP) from universities (academic spin-offs), since universities often provide IP or founders for high technology firms (Blume-Kohout, 2014; McQuaid, Smith-Doerr, & Monti 2010). One exception is Woolley (2017), who finds that almost half of nanotechnology firms founded before 2003 were started by founders employed at universities just before becoming entrepreneurs, and over 40 percent were based on university-derived IP. However, this study did not investigate the occupations of the founders and provides little insight into the distinctions of occupational backgrounds.

By and large, work has shown that academic women in the sciences are less likely to found firms than their male counterparts (e.g., Ding & Choi, 2011; Murray & Graham, 2007; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007). Since academic entrepreneurship tends to occur when professors are in their later career stages (Ding & Choi, 2011; Stephan & Lewin, 1996), the lack of female academic founders may be due to the lower overall number of female faculty in STEM-related fields, particularly at the tenured level. Indeed, the percentage of female tenure track faculty in four-year U.S. educational institutions in STEM fields ranges from 15 percent in engineering to 33 percent in biology while reaching 52 percent in psychology and

38 percent in the social sciences broadly (National Science Foundation 2018, table 9–23). In the U.S., women across academia earn less and are promoted to full professor at a slower rate than their male counterparts (e.g. Krefting, 2003; National Science Foundation, 2018, table 9–24; Yoder, 2017). Women are also disproportionately overrepresented among part-time, temporary, and non-tenure-track faculty (Curtis, 2011; National Science Foundation, 2018, table 9–24), as well as post-doctoral researchers (post-docs) and junior faculty positions (Blume-Kohout, 2014). In U.K, female academics also hold more junior positions, have less prior experience running businesses and are less likely to be involved in spinout activities (Abreu & Grinevich, 2017; Rosa & Dawson, 2006). The lack of women in advanced academic positions leads to several challenges including an overburdening of those few women in these roles (Ward & Wolf-Wendel, 2012) and a lack of role models for the next generation (Blickenstaff, 2005). Indeed, studies haves shown that women faculty in STEM fields are often burdened with a heavier service and teaching load than their male colleagues (Guarino & Borden, 2017; Hart, 2016).

Given the dominance of men in the upper echelons of academia, there should be little surprise that female academics are less likely to start a firm than male academics. Digging further, work on academic entrepreneurship has highlighted both the supply and demand concerns that underlie the underrepresentation of women in high technology entrepreneurship (see Blume-Kohout, 2014; Ding et al., 2006; Fuentes-Fuentes et al., 2012; Stephan & El-Ganainy, 2007). Supply concerns involve potential entrepreneurs and their perceptions about entrepreneurial careers, technology and the ecosystem. This include individual perceptions and attitudes, such as risk aversion, competition, perception of selling science, opportunity-seeking behavior, and family concerns, thwart the involvement of women in academic technology entrepreneurship (Blume-Kohout, 2014; Haeussler & Colyvas, 2011; Stephan & El-Ganainy, 2007). Demand concerns are social and environmental factors that hinder participation in entrepreneurship. On the demand side, external barriers that deter women from science-based academic entrepreneurship include exclusion from relevant networks, venture capitalists' bias, infrequent invitations to participate, gender discounting, overt and embedded discrimination, and masculine norms surrounding entrepreneurship (Martin, Wright, Beaven, & Matlay, 2015; Stephan & El-Ganainy, 2007). Also, careers in academia are considered to be masculine endeavors (Fotaki, 2013). The social and professional norms of academia specifically are less supportive of women entrepreneurs, often involving exclusion from commercialization opportunities or networks (Etzkowitz, Kemelgor, & Uzzi, 2000; Meng, 2016; Murray & Graham, 2007; Whittington, 2018). These factors have resulted in fewer women in STEM-related patenting (Ding et al., 2006; Whittington & Smith-Doerr, 2005), commercialization (Colyvas, Snellman, Bercovitz, & Feldman, 2012; Murray & Graham, 2007; Rosa & Dawson, 2006) and entrepreneurship (e.g., Ding & Choi, 2011; Hsu, Roberts, & Eesley, 2007; Lowe & Brambilia, 2007; Rosa & Dawson, 2006).

Previous research has started with the context and asked what the likelihood is that a person would start a company. For example, studies have examined the context of academia and determined that women there are less likely to start firms than men in academia. While useful, this work does not provide insight into those who do start firms. And outside of research on women's experience in academia-related entrepreneurship, no known studies have explored the occupational backgrounds of technology venture founders by gender. Research has shown that the technology work environment is considered hostile toward women as is the entrepreneurial realm where masculine norms prevail (e.g., Ahl, 2006; Martin et al., 2015; Stephan & El-Ganainy, 2007). As such, entry into high technology entrepreneurship can be daunting when faced with “deeply held assumptions about male and female expertise” (Martin et al., 2015: 542). Even outside of entrepreneurship, women leave STEM occupations at higher rates than men (Fouad, Fitzpatrick & Liu, 2011) or women in other professions (Glass, Sassler, Levitte, & Michelmore, 2013). The subsequent lack of existing women entrepreneurs in technology sectors to act as mentors (Orser, Riding, & Stanley 2012) as well as the ‘chilly climate’ in the social settings of technology and science workplaces (Blickenstaff, 2005) constructs a significant barrier for women entering these fields considered masculine (Powell, Bagilhole, & Dainty, 2009).

Founder Gender and Firm Funding

Financial support is critical to a company’s growth and longevity. One stream of research has focused on the financial support (venture capital, angel investments and debt) of women-owned firms. This work has highlighted the difficulties women face when seeking funding, such as fighting legitimacy challenges (Eddleston, Lang, Mitteness, & Balachandra, 2016) and receiving discouraging signals from investors (Alsos & Ljunggren, 2016). Studies typically find that female entrepreneur raise less capital overall than male entrepreneurs (Brush, de Bruin & Welter, 2009; Greene, Brush, Hart, & Saparito, 2001), and women are more likely to rely on personal resources to start their companies (Coleman & Robb, 2009). Consistently, less than five percent of venture capital (VC) funding goes to women-owned firms (Brush et al., 2004; Brush, Greene, Balachandra, & Davis, 2017; Zarya, 2017). Moreover, women are less likely to seek angel investment (nine percent of proposals come from women), but are equally likely to obtain angel funding (Becker-Blease & Sohl, 2007). The results of research on gender differences in debt financing are mixed. Some studies find that women raise less debt than men (Coleman & Robb, 2009). Other studies have not found gender differences in bank lending, either in terms of access or amount (Eddleston et al., 2016; Fabowale, Orser, & Riding, 1995;

Orser et al., 2006), but find discriminatory lending practices in the form of bankers requiring higher information disclosure of women entrepreneurs (Carter, Shaw, Lam, & Wilson, 2007; Constantinidis, Cornet, & Asandei, 2006) and women being charged higher interest rates (Wu & Chua, 2012). Generally, the evidence suggests that women are disadvantaged in the financing of their start-up. Reasons theorized for the disparity in funding have centered on differences in entrepreneurs' confidence and motivations (Brush et al., 2009; Coleman and Robb, 2009; Manolova, Brush, & Edelman, 2008) and the stereotypes and perception of role incongruence by financiers who perceive a mismatch between women and entrepreneurship (Kanze, Huang, Conley, & Higgins, 2018; Malmstrom, Johansson, & Wincent, 2017). These funding challenges have long-term ramifications for the economy, since a lack of financial support hinders firm growth (e.g. Alsos, Isaksen, & Ljunggren, 2006; Brush et al., 2004; Coleman & Robb, 2009; Marlow & Patton, 2005) and industries more broadly.

This body of work has largely treated women as a homogeneous group, neglecting the specific human capital of the founders that has proven essential for investors' evaluation of firms (Matusik, George, & Heeley, 2008). Indeed, VC decision-making has been well studied, mainly the positive role of the founder's human capital such as entrepreneurial experience (Hsu, 1997; Matusik et al., 2008), managerial experience and technical expertise (Da Rin, Hellmann, & Puri, 2011; Hisrich & Jankowicz, 1990). Similarly, founders with advanced degrees are more likely to obtain VC funding (Gimmons & Levie, 2010; Hsu, 1997). Logic suggests that women with doctoral degrees may obtain VC with fewer challenges than other founders. Human capital theory does not attend to the differences in outcomes when human capital is the same but experienced differently, such as men and women with STEM-related doctoral degrees. Treating women as a homogeneous group neglects to take into the heterogeneity of human capital and, more importantly, how similar human capital may be experienced in multiple ways and regarded by investors differently.

Founder Gender and the Performance of New Ventures

Work on the performance of nascent ventures with regards to founder gender has resulted in conflicting findings, depending on the methods and the context of the studies (Jennings & Brush, 2013; Kalnins & Williams, 2014). For example, some studies find that women-owned businesses are less likely to survive than other firms (e.g., Boden Jr. & Nucci, 2000; Carter, Williams, & Reynolds, 1997; Fairlie & Robb, 2009; Robb, 2002) and that female entrepreneurs are more likely to close their firms voluntarily than male entrepreneurs (Justo, DeTienne & Sieger, 2015). Similarly, work has shown that firms started by women have lower sales than those started by men (Chaganti & Parasuraman, 1996). Other studies find that gender-specific differences in survival and growth disappear when models control for industry and size (e.g., Chell & Baines, 1998; Cooper, Gimeno-Gascon, & Woo, 1994; Du Rietz & Henrekson, 2000; Kalleberg & Leicht, 1991; Rosa et al., 1996). In fact, Robb and Watson (2012) find that firms started by women did not perform significantly differently than other firms on three performance measures: survival, return on assets, and risk-adjusted Sharpe ratio. In certain industries, such as advertising, business services, education, and clothing, firms owned by women perform better than those owned by men (Kalnins & Williams, 2014). Hence, the relationship between founder gender and firm performance remains unclear.

One reason for the inconsistent results may be the treatment of each gender as a homogeneous group, as discussed. In fact, conflicting results should be expected; comparing firms by the gender of their founders is an oversimplification. It is illogical, for example, to expect all male-led firms to perform the same. Instead, understanding the heterogeneity of women founders will lead to more consistent expectations of their firms' performance and will enhance theory building. Nonetheless, there is a dearth of work in this area and confusion remains (Blume-Kohout, 2014; Wynarczyk & Renner 2006).

On the one hand, given the depth and breadth of the challenges women entrepreneurs in technology face, one could expect their firms to perform poorly. Women founding firms in STEM-related fields face both career and field-specific obstacles. For one, management literature finds that entrepreneurship is considered a masculine endeavor (Ahl, 2006; Bird & Brush, 2002; Eddleston et al., 2016; Gupta, Turban, Wasti, & Sikdar, 2009). At the same time, STEM fields are considered masculine (Marlow & McAdams, 2012). Gender role congruity theory underscores the inherent discord between women and heightened masculine settings, such as high technology entrepreneurship (Eagly & Karau, 2002). Indeed, women technology entrepreneurs must overcome stereotypes, discrimination, and exclusion from networks (Blume-Kohout, 2014; Haeussler & Colyvas, 2011; Rosa & Dawson, 2006; Stephan & El-Ganainy, 2007), which typically lead to difficulty building legitimacy and firm growth (Eddleston et al., 2016).

On the other hand, women starting firms in technology fields may have qualities and characteristics that make them better prepared to succeed. Also, the incongruity of gender and role may be beneficial. For example, women with technology careers have chosen to work in a fairly unsupportive environment, which may suggest that they are aware of the challenges and may even be well-suited to thrive in this setting. Similarly, overcoming the inherent obstacles for a woman founding a technology firm indicates the tenacity and perseverance necessary for successful entrepreneurs: some may even find these challenges motivating. Indeed, women who stay in engineering careers are reported to have higher self-efficacy, identify with the profession, and be motivated by the challenges of engineering (Buse, Bilimoria, & Perelli, 2013). As such, we would expect their firms to perform better. Thus, the question about the performance of high technology firms founded by women remains unresolved.

Teams

It is well established that team heterogeneity in function and education are beneficial to a firm's performance, due to the wider range of voices for decision-making (e.g., Ensley & Hmieleski, 2005; Ruef, Aldrich, & Carter, 2003; Beckman, Burton, & O'Reilly, 2007). For founding teams, heterogeneity with regards to blending the backgrounds of founders (e.g., including those with academic and those with business backgrounds) is linked to better employee and sales growth (Visintin & Pittino, 2014). Yet, it is unclear if founding teams also benefit from gender heterogeneity as studies have shown that teams more broadly with gender diversity do not perform better or worse (Chowdhury, 2005; Hoogendoorn, Oosterbeek, & Van Praag, 2013). Work on corporate boards of directors suggest that a critical mass is needed before gender diversity influences a firm's financial performance or innovation (Konrad, Kramer, & Erkut, 2008; Torchia, Calabro, & Huse, 2011; Westphal & Milton, 2000). Founding teams, which average fewer than three members, tend to be smaller than corporate boards, which average nine members (Beckman et al., 2007; Lukomnik, 2017). Thus, establishing the role of critical mass is less relevant in nascent firms. Nevertheless, female founders may help the firm establish a broader understanding of the technology and market by bringing unique and under-represented views to the team (Post & Byron, 2015). The addition of a woman's social capital and experience diversifies and expands the founding team's resources. Godwin and colleagues

(2006) argue that women can overcome concerns of gender role incongruity and legitimacy by partnering with a male co-founder, particularly in male-dominated contexts. This does not take into account the female entrepreneurs human capital that may outweigh the benefit of simply adding a male co-founder. As noted above, gender is an over-simplistic view of diversity. We should ask: Is a founder's gender, education or work experience more salient to the external audience? Team members' experiences and backgrounds also contribute to the team's decision-making performance and ability to obtain resources. Thus, the *type* of heterogeneity may be more important than the amount.

Summary

In summary, several questions remain about this important phenomenon that are poorly addressed with current theories. First, we know little about women who start high technology firms. It is not clear if there is any difference in education or occupational backgrounds for technology entrepreneurs by gender. Conflicting results from studies on firm performance has led to little consensus regarding how firms started by women and men differ in this regard. It remains unclear if heterogeneity in women's backgrounds leads to different outcomes such as VC funding. In response, this study explores the backgrounds of female and male high technology entrepreneurs to generate new evidence and theory on a timely and important topic.

METHODS

Research Setting

To examine the backgrounds of women founders of high technology firms, this study uses a database of U.S. nanotechnology firms. Nanotechnology is an exceptionally useful setting to study STEM, since the field incorporates each of the four STEM areas: science, technology, engineering and math. Nearly every industry, ranging from biotechnology to consumer products, uses nanotechnology (National Nanotechnology Coordination Office, 2007). Nanotechnology was developed over the history of science, but in 1981 the scanning tunnelling microscope (STM) was invented, which enabled scientists to observe, move, and modify a nanoscale sample in three dimensions (Rothaermel & Thursby, 2007; Smalley, 1999). The STM is considered the foundational technology supporting nanotechnology because intrinsic in nanotechnology is the ability to modify at the nanoscale. As such, no nanotechnology-specific firm was founded before 1981 (Woolley, 2010). Thus, the year 1981 signifies the earliest year of possible nanotechnology entrepreneurship and serves as the year of the earliest relevant data. This study starts here, ensuring that the data are not left-censored, whereby the origins of an event occur before the opening of the observation window (Blossfeld & Rohwer, 2002; Yamaguchi, 1991).

Data

The database consists of all nanotechnology firms started in the U.S. before 2011, compiled from 10,000 pages of industry lists, directories, press releases, university websites, scientific publications, and web sites related to nanotechnology.[3] These data were aggregated and augmented with information about nanotechnology firms from PR Newswire and PriceWaterhouseCoopers' VC site. To be included in the database, each firm was analyzed to determine if it fit the criteria for being a nanotechnology firm: a single-business venture, founded to develop, produce, and sell nanotechnology products on the merchant market. Specifically, included firms must have more than 50 percent of their activities, such as products, R&D, or

[3] Data sources include Nano Science and Technology Institute, NanoInvestorNews, NanoMarkets, NanoTechWire, Small Times Media, Lux Capital, and the Foresight Institute.

sales, derived from or related to nanotechnology. If a firm could not manipulate components at the nanoscale, it was not considered to use nanotechnology and was excluded from the database. When data were unavailable about a firm's sales or finances, its level of nanotechnology activity was identified by the firm's products, patents, and technology data. Several sources of data supplied these details, such as the firms' websites, the United States Patent and Trademark Office, press releases, and news articles. This classification process is similar to previous works that also identified new technology firms (e.g., Schoonhoven, Eisenhardt, & Lyman, 1990; Woolley, 2017). The database consists of 613 firms and 18 firms were dropped due to lack of reliable data for the founding teams. The resulting sample totaled 595 firms.[4]

Dependent variables.

Firm survival is often used as a dichotomous measure of success: either the firm succeeds and is alive or fails and is dead (Wennberg, Wiklund, DeTienne, & Cardon, 2010). For the most part, all firm exits have been treated as a failure in the literature. However, not all firms that stop operations do so due to their failure in the market. For example, firms that are acquired are often targeted because of their strong market performance or valuable assets. Investors encourage the acquisition of their portfolio firms as a mechanism to obtain a return on their investments. Some entrepreneurs actively aspire to have their firms acquired. Thus, this study uses acquisitions and firm dissolutions as contrasting mechanisms for firm exits (Fortune & Mitchell, 2012). Recent

[4] A subset of these data was compared with that from researchers who used a similar process to identify nanotechnology firms. Resulting inter-rater agreement was almost 90 percent (see Wang & Shapira, 2012 and Woolley, 2017). Any firms not in agreement were analyzed using the discussed criteria. No additional firms met the criteria. Although it is likely that nearly all new nanotechnology firms have been captured in this database, if the founders of a company with nanotechnology capabilities chose to not be involved in the nanotechnology community, had no nanotechnology-related patents or grants, did not expose their existence, and were not known to other community members, the firm would not be included in this study. Since nanotechnology is science-based and there are very few people with the substantial knowledge of the technology needed for such a commercial endeavor, it is unlikely that a firm would remain undetected.

research has started to distinguish between firms that end in distress (low performance) and those that are closed while performing well (Bates, 2005; Wennberg et al., 2010; DeTienne & Cardon, 2012; Woolley, 2017). To capture the variation in firm closures, this study differentiates between business closures due to acquisition or merger and those due to bankruptcy, liquidation, and dissolution. Additionally, obtaining VC funding is a positive milestone for start-ups, as it indicates external validation of their business model by experienced investors. In high technology fields, VC is particularly important, since starting a firm in this market is especially costly. Thus, obtaining VC can be an alternative measure of success. For each type of outcome, the following variables were collected or constructed: a dichotomous variable of outcome attainment, year of outcome, and time between firm founding and outcome.

Independent variables.

A total of 1178 founders were identified for these firms. Data were collected on each founder, including education, work history and gender, from online databases and profiles such as those listed above, university websites, faculty profiles, curriculum vitae, firm listings, Crunchbase, and LinkedIn. Next, separate variable using binary measures capture the founder's level of education (bachelor, master, doctorate, or other). Separate variables with binary variables represent the founder's work history in terms of position (professor, research scientist, student, C-level executive, non-C-level manager, serial entrepreneur and non-entrepreneur executive).[5] Position and employer variables are not mutually exclusive, as founders sometimes held more than one position simultaneously. As each individual could have more than one role (e.g., professor and serial entrepreneur), the proportion of founders with each background was

[5] Research scientists were identified as those faculty and post-doc researchers who did not have professorship titles or designations.

calculated out of the total number of founders.[6] The models examining team composition (e.g., team with female professor and male serial entrepreneur) used a binary designation if both types of founder were listed on the firm's documentation at the time of start-up.

Control variables.

Since the year a firm was started can influence its mortality (Singh, Tucker, & House, 1986), the models control for the year of the firm's founding. The number of nanotechnology firms alive each year and the square of that number were included to control for density dependence (Carroll & Hannan, 1989; Hannan & Freeman, 1988). To ensure that the outcomes of firms are not simply a reflection of overall firm activity in the economy, the number of firm closures each year in the U.S. was included (Hannan & Freeman, 1988), as well as the year-end NASDAQ composite. Models for obtaining VC funding included a control for VC funding in the U.S. All such environmental control variables were taken at a two-year lag to provide time for the macro-level condition to have an effect and were standardized.[7] Finally, all models control for the firm's industry and whether the firm was founded by a team or solo entrepreneur.

Analysis

Descriptive statistics for female and male founders were generated and analyzed using t-tests. The models report Satterthwaite's degrees of freedom, since the variances of the two groups are not assumed to be equal. This is a more conservative approach that lessens the likelihood of errors (Zaiontz, 2017).

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[6] As robustness checks, all models were run using dummy variables for the existence of a founder with a particular background on the team (e.g., team with at least one female serial entrepreneur). Results were the same.

[7] As robustness checks, geography and the number of founders were included as controls, but did not show significance and were thus not included in the models.

Firm outcomes were analyzed using event history analyses on the data using STATA with maximum likelihood estimation and robust standard errors. Data with consistently decreasing survival prospects are best modeled with Weibull, Gompertz, and exponential distributions. The Weibull distribution was chosen to accommodate the monotonic effect of time, since the hazard rates observed in these data were not constant over time (see Box-Steffensmeier & Jones, 1997). Models can be compared by considering the difference in the log-likelihood ratios, using the chi-square distribution (Blossfeld & Rohwer, 2002). This comparison showed that the best fitting survival model for the data was the Weibull failure (event) time model.[8] The equation for the Weibull distribution (Allison, 2014) is:

$$\log h(t) = b_0 + b_1x_1 + b_2x_2 + c \log t$$

where h(t) is the hazard function, b_0, b_1, b_2, and c are constants to be estimated, and *t* signifies time. Hazard ratios were estimated such that values over 1 indicate an increase in the likelihood that the covariate influenced the dependent variable, and values under 1 indicate a lower likelihood of influence by the covariate.

FINDINGS

The first section of the findings provides an overview of founders' backgrounds and the types of firms. The years of firm founding, education trends, and the industries of the firms are examined to discern macro-level patterns. The second section of the findings discusses firm outcomes; specifically, the models of the likelihood that a firm suffers from a negative closure, is acquired, or obtains VC funding.

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[8] As a robustness check, all models were compared to their equivalent using the exponential distribution. The findings did not vary. Additionally, models were run using a dichotomous measure for independent variables indicating the existence of a type of person on the founding team (e.g., at least one male serial entrepreneur on the team). These models varied little from those using the proportion of each founder type.

Founders and Their Firms

In total, about 15 percent of nanotechnology firms started before 2011 had women on the founding team. However, the percentage started each year by women founders fluctuated greatly, peaking in 2004. The types of firms that these entrepreneurs start provide insight into the context, founding team backgrounds, and firm outcomes. Figure 2 shows the number of new nanotechnology firms founded each year from 1994 through 2010 and the percentage with women founders. Of the firms with women founders, 13 percent were founded by solo entrepreneurs, or about 2.2 percent of the total sample. Women tended to found firms with men, but not with other women: only 1.3 percent of all firms were started with more than one woman on the founding team. All of the firms with more than one female entrepreneur founder were started after the year 2000 and only one of these firms has closed. Conversely, 96 percent of the firms had men on the founding team and 33 percent of firms were started by solo men.

Insert Figure 2 about here

Table 2 shows the founders' background, including education and work experience, along with the results of t-tests comparing men and women founders. Looking at the academic background of the founders, women are more likely to have worked at universities than men, but with different roles. Difference in academic occupations had marginal significance. Men are more likely to have been professors than women (30 percent versus 22 percent, respectively), and women are more likely to have worked as research scientists and post-docs than men (11 percent vs 6 percent, respectively), both only at a 0.1 significance level. Almost two-thirds of both female and male founders have doctorates. Together, these findings debunk the myth that women entrepreneurs are less likely to have academic backgrounds than men.

The breakdown of founders' prior occupations outside of academia is also shown in Table 2. Since most serial entrepreneurs were also C-level executives, the table differentiates between serial entrepreneurs and non-entrepreneur C-level executives. Over half of both female and male founders have backgrounds in business roles. Women are less likely to have had executive positions before starting their firms than men, but the significance level of the difference is negligible at 0.1. Though lower, there is no significant gender difference in the percentage of founders who are serial entrepreneurs. Overall, these data indicate that there is little difference in the educational and occupational backgrounds of female and male entrepreneurs of high technology firms.

In the sample of nanotechnology firms analyzed here, 63 percent of the female founders earned doctoral degrees. To examine the nuances of education and occupation, the female founders' fields of study were obtained and triangulated across multiple sources including their curriculum vitae, website biographies, and LinkedIn profiles.[9] Almost all of the doctorates earned by female nanotechnology entrepreneurs (97 percent) are in STEM related fields. Over one-third (36 percent) are in chemistry-related fields, such as chemistry, chemical engineering, or biochemistry. Almost 20 percent are in physics and bio-physics, 20 percent are in engineering and materials sciences, and another 20 percent are in biology-related fields, such as bioengineering and molecular biology. Although the fields are similar, the institutions from which the doctorates were earned varied. In fact, 45 different universities are represented in the sample. Furthermore, the timing of their doctoral education was diverse; almost half of the

[9] The author thanks the anonymous reviewer for suggesting this analysis.

female founders with doctorates earning their graduate degree in the 1990s and one-quarter earned it after 2000. Two percent of firms were started by teams of professors and their graduate students, for both women and men. Thus, there is little evidence of overlap in mentoring or institutional experiences at universities among these women. Of the women who started firms with one or more co-founders, half had worked with at least one of her co-founders before starting their new ventures (either in academia or business environments) and one-third started firms with male serial entrepreneurs.

Insert Table 2 and Figure 3 about here

Industries

Figure 3 shows the breakdown of nanotechnology firms by industry. Over one-third of all nanotechnology companies, regardless of founders' gender, are in the materials industry. These firms manufacture nanoscale materials, such as graphene and carbon nanotubes. Almost a quarter (24 percent) of firms founded by women are in biotechnology, compared to 14 percent of firms started by men. These findings concur with McQuaid and colleagues (2010) findings that 21 percent of New England biotechnology firms started in 2006 had women founders. The pharmaceutical industry is also more popular for women founders than male founders, who are more likely to start firms in the instrumentation and energy industries.

As mentioned earlier, Table 1 summarizes the percentage of doctorates earned by women in science and engineering fields. The table indicates that, while the overall number of STEM doctorates is increasing, the increases across fields vary considerably. These data show a relationship between the fields in which STEM degrees are earned and the industries in which women are starting firms. The fields most relevant to nanotechnology firms are engineering, physical sciences, mathematics, computer sciences, and biology/agricultural sciences. Notably, the fields with the highest increase in the percentage of women earning doctoral degrees from 1988 to 2015—earth, atmospheric, and ocean sciences (an increase of 24 percent), and biological and agricultural sciences (an increase of 20 percent)—are closely associated with those nanotechnology industries with the most women founders, namely, biotechnology and pharmaceuticals. Engineering has the lowest percentage of female doctoral recipients (23 percent) and is closely linked to the nanotechnology-related industries with the lowest percentage of women founders, semiconductors and electronics, (three percent and zero percent respectively). While much attention has been paid to increasing the number of women in STEM fields broadly, the variance of representation in fields, both in doctorates and start-ups, suggests that more attention should be paid to the heterogeneity of fields within the STEM arena.

Insert Tables 3 and 4 about here

Firm Outcomes

Table 3 shows the descriptive statistics and the correlations of the firm-level data. Table 4 shows the results from the event history analysis for bankruptcies, asset sales, and other firm closures that are not attributable to favorable circumstances such as an acquisition (Models 1-4). Table 5 reports the results for the likelihood that a firm was acquired, and Table 6 reports the likelihood that the firm received VC funding. The first model in each of these tables includes the control variables. Model 2 (Table 4) shows that firms with women founders are not more or less likely to suffer a negative closure than those without women founders. Model 3 specifies the founders' previous employment roles and shows that firms with founders who were female professors or male executives are more likely to suffer a negative closure than other firms, while female research scientists or serial entrepreneurs are less likely to have their firm close for a negative reason. Model 4 shows that founders with doctoral degrees, both women and men, are less likely to have a firm with a negative closure.

Table 5 shows the event history analysis for firm acquisitions and includes Models 5 through 8. Model 5 includes the control variables. Model 6 shows no relationship between founder gender and firm acquisitions. Model 7 indicates that firms started by male serial entrepreneurs or women professors are less likely to be acquired, with the latter at a marginal significance level. However, firms started by research scientists and post-docs, either women or men, are more likely to be acquired. Model 8 shows that firms founded by a female with a doctoral degree are 59 percent less likely to be acquired than other firms.

Obtaining VC is the dependent variable in Table 6, which includes Models 9 through 12. Model 9 is the control model, while Model 10 shows that, similar to the findings in previous studies (Brush et al., 2009; Brush et al., 2017; Greene et al., 2001; Zarya, 2017), firms started by women are less likely to obtain VC. Looking at the employment backgrounds of the founders, Model 11 shows that firms started by female professors, research scientists, and executives are less likely to obtain VC, while female serial entrepreneurs and male executives and entrepreneurs are more likely to obtain VC. Model 12 shows that firms started by women with doctoral degrees are 39 percent less likely to obtain VC than other firms, while those started by men with doctoral degrees are 24 percent more likely.

To examine how team founders might complement one another, Models 13 through 15 in Table 7 examine how heterogeneous founder backgrounds influence outcomes.[10] The direct effects of the founder backgrounds are consistent with previous models. Model 13 indicates that,

[10] These models include dichotomous measures to indicate if a type of founder is on the team.

while firms by female professor or male executives are more likely to suffer a negative closure, pairing these founders together actually leads to a lower likelihood of a negative closure. Model 14 considers the team composition with regard to firm acquisitions. Unfortunately, the low number of these types of teams with acquisitions restrict the analyses. However, it is worth noting that teams with women entrepreneurs and male professors were highly likely to be acquired, compared to other firms. Taken together, teams with female entrepreneurs and male professors are generally likely to close on both positive and negative terms, which may be related to obtaining VC funding, as shown in Model 15. Teams with female entrepreneurs and male professors were less likely to obtain VC funding, even though women serial entrepreneurs are more likely to obtain funding. In contrast, the combination of female executives and male professors strengthened a firm's likelihood of obtaining VC.

Insert Tables 5-7 about here

DISCUSSION

Despite undermining stereotypes and unsupportive norms, women from a variety of backgrounds are actively pursuing careers in high technology entrepreneurship. Extant work has identified the supply and demand concerns that discourage women, particularly those from academia, from entrepreneurial careers (e.g., Blume-Kohout, 2014; Ding & Choi, 2011; Jennings & Brush, 2013). To date, however, limited work has examined the women who transcend these concerns and start firms in technology-related fields. I embarked upon this study to improve our understanding of who these women are, their backgrounds and human capital, and the firms that they create. Thus, I contribute to the entrepreneurship and founding team literature by clarifying the diversity and significance of high technology founders' education and career trajectories with respect to gender. Importantly, the findings dispel the myth that women and men who start high technology firms have different education and occupation backgrounds while highlighting that similar human capital can be regarded and experienced differently. These discoveries open new territories for research and policy, which are elaborated below.

In contrast to work that indicates that academia does not produce women entrepreneurs, about one-third of all nanotechnology founders in this study – both women and men – are either professors or research scientists. Additionally, female founders of nanotechnology firms are more likely to have previously worked for a university as a professor or research scientist than to have previously worked as an executive at a firm (Table 2). However, female and male founders were employed in different roles before starting their firms: female founders were less likely to have been professors than male founders (22 percent versus 30 percent, respectively) and more likely than to have been research scientists and post-doc researchers (11 percent versus 6 percent, respectively). This raises questions about how these career paths differ in their conduciveness for entrepreneurship. Previous work regarding women entrepreneurship in academia has not differentiated between professors and research scientists (e.g., Ding et al., 2006; Ding & Choi, 2011; Stephan & El-Ganainy, 2007) and there may be both supply- and demand-based concerns that encourage entrepreneurship for female research scientists more than professors. For example, it is possible that female research scientists and post-docs find the career prospects in academia unattractive (Whittington & Smith-Doerr, 2005) or see fewer avenues for success in academia as a career and turn to entrepreneurship as an alternative. The few female faculty members who work in STEM fields feel singled out to take on extra work because of their unique, yet isolating position as a woman in science, sometimes the only one in the department (Ward & Wolf-Wendel, 2012) and as one of the few role models (Bilimoria, Joy, & Liang, 2008;

Blickenstaff, 2005). Unfortunately, being one of the few women working in a stereotypically masculine field can bring attention and extra work, but not positive recognition (Chatman, Boisnier, Spataro, Anderson, & Berdahl, 2008). Additionally, since female professors contribute more service to the profession than their male colleagues (Guarino & Borden, 2017), they may find it difficult to engage in entrepreneurial activities that can lead to founding new ventures. Female research scientists most likely notice the inequity that comes with a professorial role and consider career options deeply. How a person conceives of and identifies with a role or field can shape her perception of self-efficacy and the likelihood that she undertakes an entrepreneurial careers (Leung & Fast, 2017). How female research scientists and professors identify with their own occupations could shape their perception of opportunities within academia and elsewhere. Additional studies on how women and men experience their occupations differently and how this influences the decision to transition into entrepreneurship will enrich the field greatly.

This study is one of the first to explore the relationship of an entrepreneur's gender, educational and occupational backgrounds, and firm outcomes in high technology sectors. Here we see that the simple indicator of founder gender alone provides little insight. When the heterogeneity of founders' backgrounds is taken into consideration with gender, a more nuanced understanding emerges. Notably, the findings suggest that it is not just the founders' backgrounds that are relevant, but what they take away from their experiences that influences how they develop their new ventures and their eventual outcomes. Just as social and professional norms vary by educational field, degree, and occupation, women and men experience these norms differently as well. Furthermore, I argue that women and men may experience similar backgrounds differently and that these experiences generate distinct human capital for founders, which, in turn, influences the success of their firms. As discussed, female professors tend to dedicate more hours to professional service than their male colleagues (Guarino & Borden, 2017; Hart, 2016), which could reduce the time available for developing their entrepreneurial ventures. Studies have not established if these expectations or norms are the same for research scientists who are at different points in their careers. Contrasting career specific norms within academia may explain the firm outcome trends for ventures started by professors versus research scientists. However, current theory does not address adequately how similar types of human capital can be regarded and experienced differently depending on gender. This is an important distinction that is undertheorized in the literature, but an exciting opportunity for development with implications for both theory and policy.

While aspirations and motivations vary by gender, these need to be considered in conjunction with a person's background instead of as a separate variable. For example, in contrast with female research scientists, female professors are more likely to start firms that suffer negative closures. While both have careers in academia, they have different career experiences and skill sets that influence how and why they develop their firms. Just as women and men often start firms for different reasons (e.g., Carter, Gartner, Shaver, & Gatewood, 2003; Cohoon, 2011; DeMartino & Barbato, 2003; Thebaud, 2015), I propose that founders' aspirations and definitions of success vary depending on how they experience their career or educational backgrounds, which in turn, influences the outcomes of their entrepreneurial endeavors. For example, research scientists who arguably have shorter career histories, will likely have different reasons for starting firms than professors or those founders with business backgrounds, which can help explain why firms created by research scientists are more likely to be acquired and less likely to suffer negative closures. Female professors may aspire to create firms that do not fit the typical mold for acquisition targets, which could lead to lower likelihood of acquisition. In contrast, firms started by female professors may be less scalable and thus less likely to be acquired or funded. These speculations cannot be address by this study, but I hope that my findings provoke others to investigate such interesting questions.

The finding that female serial entrepreneurs are more likely to obtain VC while other female founders were less likely also highlights the limitations in prior studies that treat women entrepreneurs as a homogeneous group, and this discovery is an important distinction in our understanding of start-up financing. Potentially, these founders may have had previous experience with VC funding that enabled them to overcome the difficulties reported by women seeking investments for their firms (see Benner, 2017; Mundy, 2017). However, the data in this study do not indicate if these founders had obtained VC for previous firms. Previous studies have argued that female entrepreneurs tend to value independence over financial success, status and innovation compared to male entrepreneurs who value financial gains, self-realization, and autonomy (Carter, Gartner, Shaver, & Gatewood, 2003; Manolova et al., 2008), but both female and male serial entrepreneurs are more likely to obtain VC funding than other firms. Further inquiry would prove useful for the next generation of female technology entrepreneurs and those organizations seeking to empower women through greater equality and opportunities.

In contrast to previous studies (Gimmons & Levie, 2010; Hsu, 1997), this study finds that the positive relationship between doctoral degrees and VC funding is not universal. For nanotechnology firms, female founders do not benefit the same way that male founders do, in that women with doctoral degrees are less likely to obtain VC funding and men with doctoral degrees are more likely to obtain VC funding than other founders. These findings challenge the premise of role congruity theory since women with STEM doctorates have an identity more consistent with high technology entrepreneurship than female founders who lack such an advanced degree. A STEM-related doctorate indicates advanced scientific education (Watson, Stewart, & BarNir, 2003; Sapienza & Grimm, 1997) and in-depth technology knowledge (Ding & Choi, 2011; Clarysse, Wright, & Van de Velde, 2011), both of which benefit high technology start-ups. Although the academic environment in STEM is not friendly towards women, having an academic background (e.g. doctorate, work experience) in a STEM-related field should reduce the perceived incongruity between gender and high technology careers. However, these attributes were not beneficial enough to attract investment. Given the importance of experience and technological expertise, these findings are unexpected and worthy of further study. Thus, extending role congruity theory to incorporate gender and context is natural development for future research.

Challenges continue and female academics and executives continue to have difficulty raising VC. These findings are generally consistent with previous studies that find female entrepreneurs raising less financing than male entrepreneurs (Brush et al., 2009; Malmstrom et al., 2017; Verheul & Thurik, 2001). These results may be due to fewer women in these positions seeking VC, or perhaps that their firms are less attractive due to perception, opportunity, quality, or gender homophily (Becker-Blease & Sohl, 2007). On one hand, female executives were able to improve the likelihood of obtaining funding by partnering with a male professor, indicating that heterogeneity in gender and background benefited teams in this regard. On the other hand, female professors and entrepreneurs were not able to benefit by diversifying their teams in terms of gender and occupation. This discovery underscores the fact that heterogeneity is more complicated than simply having a mix of genders and occupational background. Getting the right people together is clearly more important than meeting quotas.

Team composition and collaboration trends provided useful insight into how founders find cofounders. The findings show that a minority of nanotechnology firms had a woman on the founding team (15 percent) while almost all firms had men on the founding team (96 percent). Almost 87 percent of the firms founded by women had more than one founder on the team, compared to 60 percent of firms with male founders, indicating that women are more likely to collaborate with others during start-up. However, women do not collaborate with other women to found firms, as only about 10 percent of the firms started by women had more than one female founder. As a 13 percent of firms founded by women had solo entrepreneurs, over 74 percent of firms started by women had a male collaborator. This may be due to the relatively small number of women active in the entrepreneurial space. Of the 1178 founders of the 595 firms in the database, only 99 were women, 17 percent of whom had started more than one company (see Table 2). Women entrepreneurs with business backgrounds used their networks to find co-founders, principally in their places of work as half of those who founded the nanotechnology firm in teams had worked with at least one of her co-founders before starting their new ventures. Likewise, half of academic women founders also worked with their co-founders before starting their firms (not as students). Additionally, one-third of the women started firms with male serial entrepreneurs. These figures indicate that opportunities for collaboration between coworkers maybe an understudied mechanism to bolster women entrepreneurship in high technology fields. While studies have shown that gender diversity in teams does not equate to differences in performance (Chowdhury, 2005; Hoogendoorn et al., 2013), in terms of patenting, women are more productive when collaborating with other women (Whittington, 2018). This implies that an increase in the number of women in science will benefit not only their productivity, but also innovation more broadly. Future research developing theory regarding gender, collaboration and entrepreneurship may prove useful in understanding career trajectories and motivations more deeply, especially with regards to the role of mentoring and collaboration.

The study has implications for policymakers. For one, instead of encouraging more women to start high technology firms, policymakers should identify the backgrounds, characteristics, and motivations of potential founders that are most aligned with technological success. Simply starting more firms is not a strong goal if those firms are destined to fail. It is imperative that policymakers encourage entrepreneurship for the right reasons. Supporting the creation of firms with a high likelihood of economic potential, such as jobs or revenue growth, could prove more useful to society. Additionally, program and policy goals should match the aspirations of the founders. Research shows that women and men entrepreneurs have contrasting, yet similar reasons for starting firms (e.g., Carter et al., 2003; Thebaud, 2015); it is not clear how these motivations differ when career path and mentoring are considered. For example, given the norms and training differences between women and men in academia, it follows that their aspirations would differ when starting a firm. This may or may not, be true for entrepreneurs with industrial backgrounds. The differences between founding rates and outcomes between women entrepreneurs from academia suggests that university administrators and policymakers should consider additional support for academic spinouts by women.

As with any study, this work is constrained by limitations that suggest additional opportunities for future research. For example, the data do not identify the personal or professional motivations of these founders. Justo and colleagues (2015) find that women founders in spousal relationships cited personal reasons for closing their company, while male founders in spousal relationships cited the ability to pursue other opportunities. In the case of bankruptcy, personal motivations to avoid bankruptcy may vary by gender, family status, or occupation. The study is also limited by the lack of data regarding the field of founders' education or profession. The data indicate a relationship between the growth of STEM doctoral degrees and start-ups when field and industry are taken into consideration. As professional norms vary by field, founders inevitably experience variation despite experience in STEM fields. The findings control for industry, but not for field of study or previous employment. Additional data on founder education may help clarify the relationship between education, professional field and firm performance. Similarly, the benefit of the cross-industry setting of nanotechnology is also a liability. While nanotechnology enables the examination of founders across STEM fields, representative of high technology sectors, the findings may not be generalizable in specific fields. For example, the professional norms and contextual pressures in materials and nano-biotechnology, the two fields with the most firms with female founders as shown in Figure 3, may differ from other STEM-based fields. Unfortunately, the low number of firms in each industry prevented a comparative study. Future research drawing from a larger sample of STEM-based firms would prove valuable for a comparative study between fields.

CONCLUSIONS

Work in the area of high technology entrepreneurship has concentrated on new ventures resulting from IP from universities (academic spin-offs), with comparatively limited research examining of the relationship between gender, technology, and entrepreneurship outside of academia (Wynarczyk & Renner 2006). In this study, I attempt to advance our understanding of this relationship by establishing a set of facts regarding women in high technology entrepreneurship. Without knowing the current state of the field, policy makers are ill-equipped to make effective decisions on interventions to support nascent entrepreneurship for women in high technology sectors. This study helps establish a baseline by which we can measure the effectiveness of policy instruments enacted.

I also attempt to improve our understanding of which women start technology firms and how their backgrounds are related to the outcomes of their firms. Often, researchers are plagued with the difficulty of determining which variables are salient and how to measure them. The results confirm that the gender of a founder is but one characteristic of a founding team. More research identifying other relevant aspects of human capital heterogeneity, not only of firm founders, but also of investors and acquiring firm executives, will surely prove worthwhile.

The experience of women in technology is just one example of how social norms and conventions change over time. Almost half of the female founders with doctorates earned their doctoral degrees in the 1990s and one-quarter earned that degree after 2000, but the year of doctorate was not related to the firm outcomes. Indeed, all of the firms with more than one female entrepreneur founder were started after the year 2000, indicating that entrepreneurial collaboration among women is increasing. However, the volume of reports from female entrepreneurs about the challenges, stereotypes, and harassment they experience in high-technology sectors (see Benner, 2017; Mundy, 2017) indicates that this is a setting in which gender is exceptionally salient and difficulties for women remain. Organizations such as the WISE (Women In Science and Engineering) Campaign and social media campaigns such as #WomenInSTEM, and #distractinglysexy[11] are challenging the assumptions and stereotypes pervasive across technology. It will be exciting to see how customs and norms further evolve.

[11] #WomenInSTEM started in 2009 to recognize Rebecca Robinson for her work to promote science and engineering to women. #distractinglysexy emerged in 2015 in response to Dr. Tim Hunt's comment working with "girls" in laboratories being difficult because: "Three things happen when they are in the lab: you fall in love with them, they fall in love with you, and when you criticize them they cry."

TABLES AND FIGURES

Table 1. Percentage of doctorates awarded to women by field of study – 1988, 1997, 2006, and 2015.

Field	1988	1997	2006	2015	'88-'15 change
Science and engineering, total	27.0%	32.8%	38.4%	40.8%	13.8%
Engineering	6.8%	12.3%	20.2%	23.2%	16.4%
Sciences	32.1%	38.8%	44.2%	46.9%	14.8%
Physical sciences	16.9%	22.4%	27.8%	31.5%	14.6%
Earth, atmospheric, & ocean sciences	19.4%	23.7%	35.3%	43.2%	23.8%
Mathematical/computer sciences	14.0%	20.2%	25.3%	24.7%	10.7%
Biological/agricultural sciences	33.0%	40.7%	47.9%	52.5%	19.5%
Psychology	54.7%	66.6%	71.3%	72.0%	17.3%
Social sciences	34.8%	38.7%	45.7%	49.1%	14.3%
Non-S&E, total	49.0%	53.8%	57.6%	59.0%	10.0%
Health	62.2%	65.7%	67.4%	68.5%	6.3%
Humanities	43.7%	47.2%	50.0%	50.6%	6.9%
Education	55.2%	62.8%	65.1%	68.4%	13.2%
Professional / other	32.3%	39.4%	47.8%	51.7%	19.4%

SOURCE: National Science Foundation/Division of Science Resources Statistics, Survey of Earned Doctorates: Science and engineering (S&E) doctorates awarded to women (2016).

Table 2. Comparison of Individual Founders' Backgrounds of Nanotechnology Firms

	Male Founders		Female Founders		All			
	n=1079	S.E.	n=99	S.E.	n=1178	S.E.	t (S.df.)	*p*
Professor	30.2%	(0.01)	22.2%	(0.04)	29.5%	(0.01)	1.8 (121)	^
Research Scientist	5.8%	(0.01)	11.1%	(0.03)	5.4%	(0.01)	-1.7 (108)	^
Serial Entrepreneur	23.5%	(0.01)	17.2%	(0.04)	23.0%	(0.04)	1.6 (122)	
Executive (non-ENT)	17.5%	(0.01)	11.1%	(0.03)	17.0%	(0.01)	1.9 (126)	^
Ph.D.	63.6%	(0.01)	62.6%	(0.05)	63.5%	(0.01)	0.2 (117)	
University	41.4%	(0.02)	46.5%	(0.05)	41.9%	(0.01)	-1.0 (116)	
Business	59.6%	(0.01)	52.5%	(0.05)	59.0%	(0.01)	1.3 (116)	

Note: Standard errors are in parentheses. One-tail t-test was applied, ^ $p< 0.1$, * $p<0.05$.

Table 3. Descriptive Statistics (Firm Level) and Correlation Table

	Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8	9
1	Negative closure	0.31	0.46	1.00								
2	Firm Acquired	0.16	0.37	-0.27	1.00							
3	Firm Obtained VC	0.42	0.49	-0.11	0.07	1.00						
4	Year Founded	2003.18	4.62	-0.02	-0.21	0.03	1.00					
5	NASDAQ (Year end)	3444.40	968.20	-0.49	-0.49	0.06	0.29	1.00				
6	Nano firm Density	489.09	93.31	-0.35	-0.42	0.05	0.37	0.82	1.00			
7	US Firm Closures (K)	389.21	34.35	0.40	0.42	-0.04	-0.17	-0.82	-0.52	1.00		
8	US VC Investment (MM)	28.64	5.02	-0.17	-0.17	0.10	0.11	0.39	0.30	-0.27	1.00	
9	Team	0.65	0.48	0.04	0.04	0.16	0.17	-0.02	0.00	0.00	-0.05	1.00
10	Women on Team	0.15	0.36	-0.06	-0.03	-0.06	0.07	0.10	0.11	-0.06	0.01	0.18
11	Professor - Women	0.02	0.10	-0.03	-0.05	0.07	0.05	0.10	0.09	-0.08	0.02	0.09
12	Scientist / Post Doc - Women	0.01	0.07	-0.05	-0.03	-0.07	0.01	0.06	0.05	-0.05	0.02	-0.01
13	Serial Entrepreneur - Women	0.02	0.10	-0.05	-0.03	-0.03	0.06	0.08	0.06	-0.05	0.02	0.01
14	Executive - Women	0.01	0.07	0.00	-0.03	-0.06	0.04	0.05	0.04	-0.06	-0.01	0.05
15	Professor - Men	0.26	0.37	-0.05	-0.03	0.08	0.00	0.07	0.05	-0.09	0.09	0.07
16	Scientist / Post Doc - Men	0.05	0.18	-0.05	-0.02	-0.04	0.03	0.04	0.01	-0.05	0.00	0.01
17	Serial Entrepreneur - Men	0.21	0.33	0.02	0.00	0.08	0.10	-0.03	-0.04	-0.02	-0.07	0.04
18	Executive - Men	0.16	0.31	0.06	0.07	0.07	0.05	-0.09	-0.06	0.13	-0.01	-0.05
19	PhD - Women	0.05	0.18	-0.06	-0.08	-0.04	0.07	0.10	0.10	-0.08	0.02	-0.01
20	PhD - Men	0.59	0.40	-0.08	-0.04	-0.02	0.01	0.09	0.07	-0.10	0.02	-0.01

Table 3. Correlation Table – continued

	Variable	10	11	12	13	14	15	16	17	18	19	20
10	Women on Team	1.00										
11	Professor - Women	0.40	1.00									
12	Scientist / Post Doc - Women	0.27	-0.02	1.00								
13	Serial Entrepreneur - Women	0.37	0.10	0.27	1.00							
14	Executive - Women	0.32	-0.02	-0.02	0.06	1.00						
15	Professor - Men	-0.13	-0.03	0.00	-0.06	-0.07	1.00					
16	Scientist / Post Doc - Men	-0.07	-0.05	-0.02	-0.04	0.01	-0.10	1.00				
17	Serial Entrepreneur - Men	-0.12	-0.08	-0.05	-0.03	0.00	-0.14	-0.09	1.00			
18	Executive - Men	-0.14	-0.06	-0.05	-0.04	-0.06	-0.20	-0.12	-0.17	1.00		
19	PhD - Women	0.70	0.49	0.35	0.25	0.05	-0.11	-0.07	-0.12	-0.13	1.00	
20	PhD - Men	-0.28	-0.11	-0.08	-0.12	-0.08	0.38	0.17	-0.10	-0.24	-0.26	1.00

Table 4. Event History Analysis for Negative Closures

	Model 1			Model 2			Model 3			Model 4		
Variable	H.R.	S.E.	p	H.R.	S.E.	p	H.R.	S.E.	p	H.R.	S.E.	p
Year Founded	4.82	(0.32)	***	4.82	(0.39)	***	4.83	(0.32)	***	4.80	(0.31)	***
NASDAQ (Year end)	0.90	(0.06)		0.90	(0.06)		0.90	(0.06)		0.89	(0.06)	^
Nano Firm Density	0.70	(0.19)		0.70	(0.46)		0.77	(0.23)		0.61	(0.17)	^
Nano Firm Density - Squared	0.01	(0.01)	***	0.01	(0.00)	***	0.01	(0.01)	***	0.02	(0.01)	***
US Firm Closures (K)	1.25	(0.04)	***	1.25	(0.09)	***	1.21	(0.05)	***	1.24	(0.04)	***
VC Investment	0.84	(0.03)	***	0.84	(0.03)	***	0.81	(0.03)	***	0.83	(0.03)	***
Team	1.01	(0.05)		1.01	(0.06)		1.02	(0.05)		1.02	(0.05)	
Women on Team				0.97	(0.06)							
Professor - Women							2.36	(0.61)	***			
Research Scientist - Women							0.23	(0.06)	***			
Serial Entrepreneur - Women							0.63	(0.18)	^			
Executive - Women							0.84	(0.27)				
Professor - Men							0.98	(0.06)				
Research Scientist - Men							1.03	(0.17)				
Serial Entrepreneur - Men							0.97	(0.07)				
Executive - Men							1.31	(0.12)	**			
PhD - Women										0.67	(0.09)	**
PhD - Men										0.79	(0.04)	***
Constant	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***
Log pseudolikelihood	501.56			501.62			514.80			509.34		
Degrees of freedom	11			12			19			13		
Wald chi2	3244.17		***	3264.81		***	3546.05		***	3264.85		***

n= 595, Closures = 185, /ln_p = 2.58 (0.04). Standard errors in parentheses. Includes industry controls, ^ p< 0.1, * p<0.05, ** p<0.01, *** p< 0.001

Table 5. Event History Analysis for Acquisitions

Variable	Model 5 H.R.	Model 5 S.E.	Model 5 p	Model 6 H.R.	Model 6 S.E.	Model 6 p	Model 7 H.R.	Model 7 S.E.	Model 7 p	Model 8 H.R.	Model 8 S.E.	Model 8 p
Year Founded	1.22	(0.01)	***	1.22	(0.01)	***	1.23	(0.01)	***	1.22	(0.01)	***
NASDAQ (Year end)	0.51	(0.04)	***	0.51	(0.04)	***	0.50	(0.04)	***	0.52	(0.04)	***
Nano Firm Density	1.05	(0.31)		1.05	(0.31)		1.23	(0.36)		1.06	(0.31)	
Nano Firm Density - Squared	0.70	(0.22)		0.70	(0.22)		0.57	(0.18)	^	0.69	(0.22)	
US Firm Closures (K)	1.15	(0.06)	**	1.15	(0.06)	**	1.11	(0.06)	^	1.16	(0.06)	**
VC Investment	1.78	(0.13)	***	1.78	(0.13)	***	1.92	(0.15)	***	1.76	(0.13)	***
Team	1.89	(0.15)	***	1.87	(0.15)	***	1.98	(0.16)	***	1.95	(0.15)	***
Women on Team				1.06	(0.10)							
Professor - Women							0.28	(0.19)	^			
Research Scientist - Women							11.01	(2.75)	***			
Serial Entrepreneur - Women							1.77	(0.72)				
Executive - Women							0.85	(0.26)				
Professor - Men							1.03	(0.11)				
Research Scientist - Men							2.02	(0.32)	***			
Serial Entrepreneur - Men							0.67	(0.09)	***			
Executive - Men							0.93	(0.12)				
PhD - Women										0.41	(0.12)	***
PhD - Men										1.03	(0.09)	
Constant	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***
Log pseudolikelihood		-1853.86			-1853.68			-1818.07			-1847.78	
Degrees of freedom		11			12			19			13	
Wald chi2		1731.53	***		1743.22	***		1935.83	***		1749.04	***

n= 595, Acq = 107, /ln_p = 1.14 (0.04). Standard errors in parentheses. Includes industry controls, ^ p< 0.1, * p<0.05, ** p<0.01, *** p< 0.001

Table 6. Event History Analysis for Venture Capital

	Model 9			Model 10			Model 11			Model 12		
Variable	H.R.	S.E.	p	H.R.	S.E.	p	H.R.	S.E.	p	H.R.	S.E.	p
Year Founded	2.56	(0.07)	***	2.57	(0.07)	***	2.60	(0.07)	***	2.58	(0.07)	***
NASDAQ (Year-end)	0.62	(0.03)	***	0.63	(0.03)	***	0.61	(0.03)	***	0.62	(0.03)	***
Nano Firm Density	0.09	(0.01)	***	0.09	(0.01)	***	0.09	(0.01)	***	0.10	(0.01)	***
Nano Firm Density - Squared	0.11	(0.02)	***	0.10	(0.02)	***	0.11	(0.02)	***	0.10	(0.02)	***
US VC Investment (MM)	0.96	(0.01)	***	0.95	(0.01)	***	0.96	(0.01)	**	0.95	(0.01)	***
Team	1.02	(0.04)		1.09	(0.05)	*	1.10	(0.05)	*	1.04	(0.04)	
Women on Team				0.72	(0.04)	***						
Professor - Women							0.58	(0.07)	***			
Research Scientist - Women							0.26	(0.08)	***			
Serial Entrepreneur - Women							4.94	(0.72)	***			
Executive - Women							0.18	(0.04)	***			
Professor - Men							1.03	(0.06)				
Research Scientist - Men							0.95	(0.10)				
Serial Entrepreneur - Men							1.15	(0.08)	*			
Executive - Men							1.38	(0.09)	**			
PhD - Women										0.61	(0.07)	***
PhD - Men										1.24	(0.06)	***
Constant	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***
Log pseudolikelihood =		-1472.29			-1457.00			-1424.38			-1450.31	
Degrees of freedom		10			11			18			12	
Wald chi2		4173.46	***		4226.98	***		4054.16	***		4187.36	***

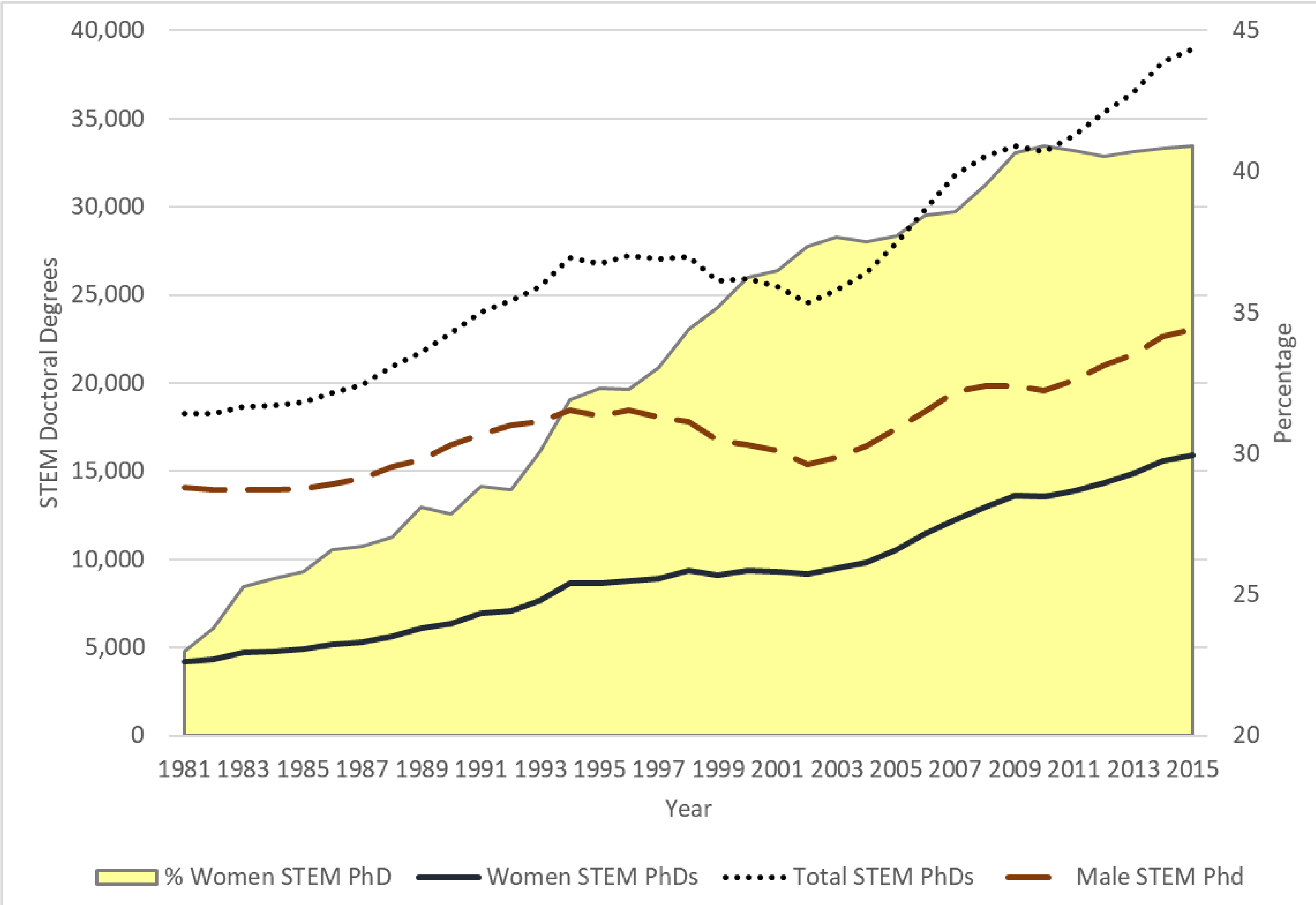
n= 595, VC = 252, /ln_p = 1.26 (0.02). Includes industry controls. Standard errors in parentheses ^ $p< 0.1$, * $p<0.05$, ** $p<0.01$, *** $p< 0.001$

Table 7. Event History Analysis of Founding Teams Composition

	Negative Closure Model 13			*Acquired* Model 14			*VC* Model 15		
	H.R.	S.E.	p	H.R.	S.E.	p	H.R.	S.E.	p
Year Founded	4.84	(0.32)	***	1.22	(0.01)	***	2.60	(0.07)	***
NASDAQ (Year-end)	0.89	(0.06)	^	0.50	(0.04)	***	0.59	(0.03)	***
Nano Firm Density	0.88	(0.26)		1.24	(0.38)		0.08	(0.01)	***
Nano Firm Density - Squared	0.01	(0.00)	***	0.57	(0.19)	^	0.12	(0.02)	***
US Firm Closures (K)	1.21	(0.04)	***	1.11	(0.06)	^			
VC Investment	0.82	(0.03)	***	1.87	(0.14)	***			
Team	1.03	(0.05)		2.08	(0.18)	***	1.03	(0.05)	
US VC Investment (MM)							0.97	(0.01)	**
Professor - Woman on team	1.61	(0.31)	**	0.58	(0.23)		0.70	(0.06)	***
Serial Entrepreneur - Woman on team	0.31	(0.06)	***	0.95	(0.33)		2.23	(0.34)	***
Executive - Woman on team	1.22	(0.25)		0.89	(0.13)		0.38	(0.03)	***
Professor - Man on team	0.91	(0.04)	*	1.00	(0.08)		1.03	(0.04)	
Serial Entrepreneur - Man on team	0.83	(0.05)	***	0.70	(0.06)	***	1.06	(0.05)	
Executive - Man on team	1.13	(0.06)	*	0.87	(0.08)		1.34	(0.06)	***
Team woman prof & man entrepreneur	3.88	(0.88)	***	0.00	(0.00)	***	1.12	(0.12)	
Team woman prof & man exec	0.57	(0.11)	**	0.00	(0.00)	***	1.30	(0.21)	
Team woman entrepreneur & man prof	7.04	(1.82)	**	7.91	(4.15)	***	0.35	(0.07)	***
Team woman exec & man prof	0.00	(0.00)	***	0.00	(0.00)	***	12.84	(2.15)	***
Constant	0.00	(0.00)	***	0.00	(0.00)	***	0.00	(0.00)	***
Log pseudolikelihood		536.24			-1822.99			-1412.29	
Degrees of freedom		21			21			21	
Wald chi2		13683.75	***		14826.77	***		4501.51	***
Time at risk		67232			68617			52249	
/ln_p	2.58	(0.04)		1.14	(0.04)		1.26	(0.02)	

n= 595, Includes industry controls, ^ p< 0.1, * p<0.05, ** p<0.01, *** p< 0.001

Figure 1. U.S. STEM Doctorates Total and Percentage Awarded to Women, Annually from 1986-2015.[12]



[12] Data from National Science Foundation/Division of Science Resources Statistics. 2016. Survey of Earned Doctorates: www.nsf.gov/statistics.

Figure 2. Number of New Nanotechnology Firms Founded Annually and the Percentage with Women Founders, 1994-2010.

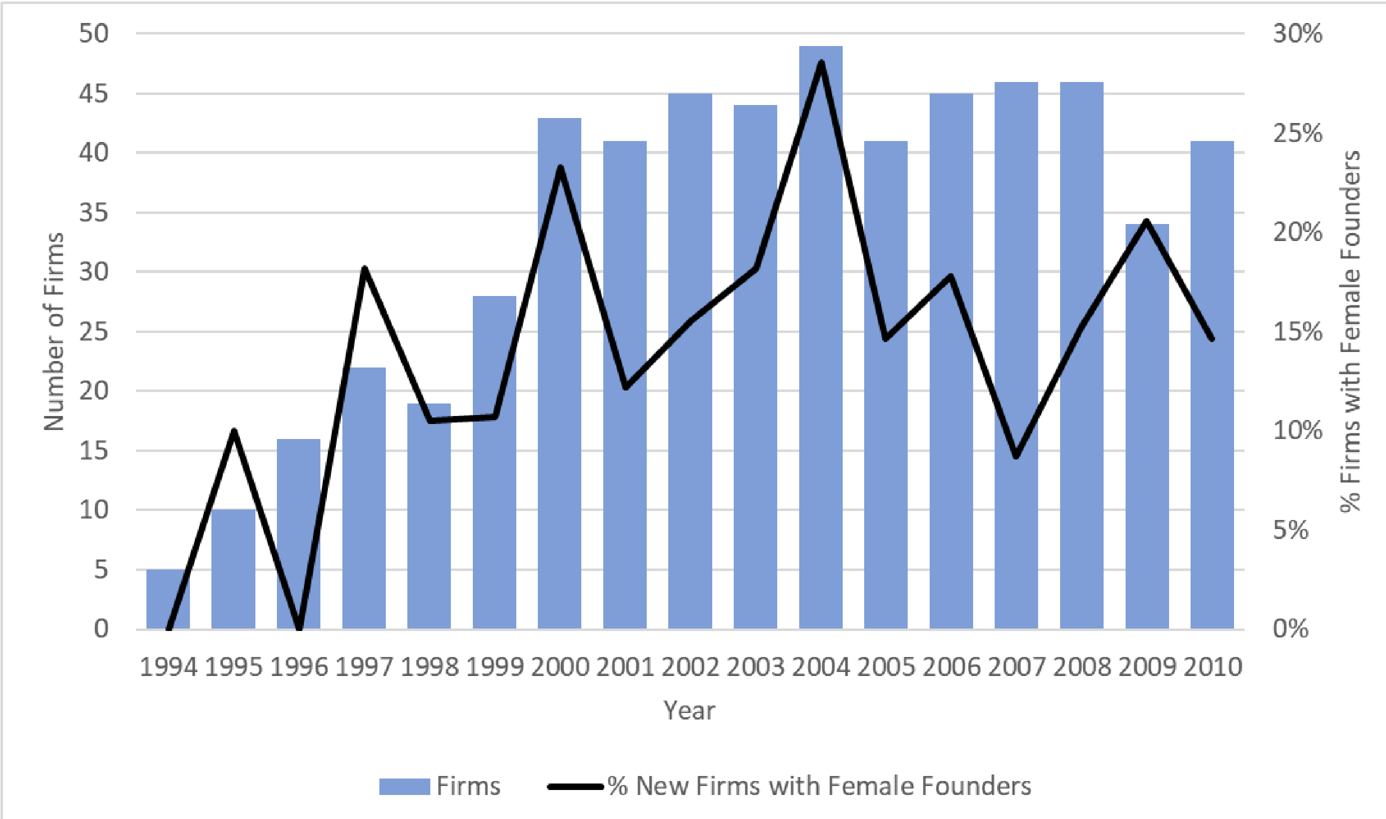
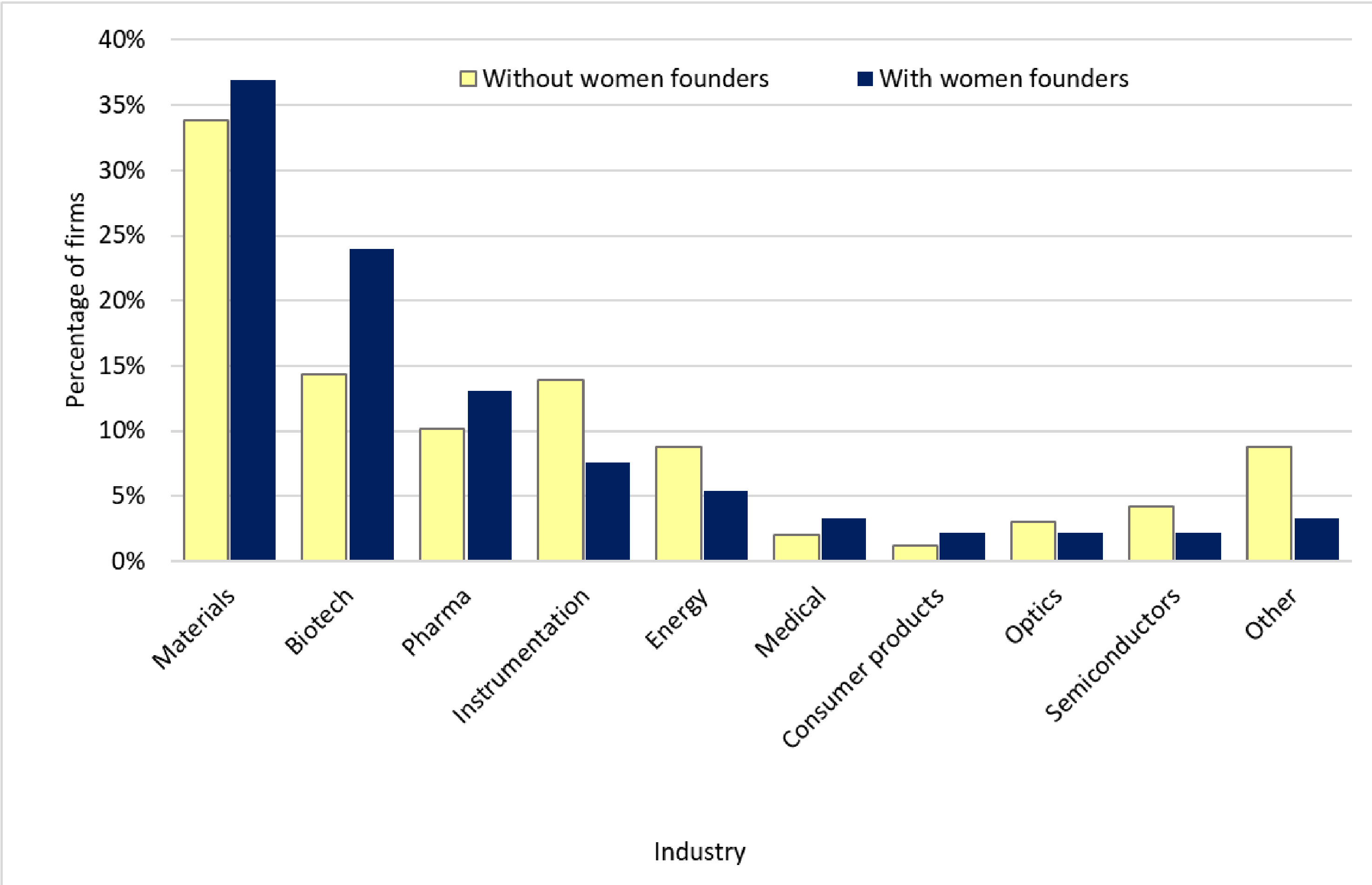


Figure 3. Industry of Nanotechnology Firms by Genders of Founders.



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