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MINING FOR NUGGETS: OPPORTUNITY EXPLORATION IN HIGH-TECHNOLOGY VENTURES

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Abstract

Entrepreneurial ventures emerging from new inventions often have several potential market opportunities. Linking the technology to the market opportunities requires a costly process of exploration, as basic research inventions entail high technological and market uncertainty. Due to managerial attention and resource constraints, it is very difficult to do explore multiple opportunities in parallel. The roles, knowledge sets and incentives of the founding members of the high-technology venture can influence how and whether these ventures explore market opportunities, but few studies have examined this relationship beyond the initial identification of these opportunities. This study takes advantage of the unique context of university spin-offs to quantify the initial opportunity exploration in 568 university high-technology ventures and investigate the relationship between this exploration and the composition of the founding team, using the behavioral theory of the firm. Results show that the level of opportunity exploration varies with the knowledge, incentives and roles played by the founders of these high-technology ventures. This study extends past research by first observing the opportunity exploration of high-technology ventures, going beyond opportunity identification. The results also suggest that more than prior entrepreneurial and educational experience is at play in determining how many paths the high-technology venture explores prior to market development. The manner in which high-technology ventures initially organize influences the early market opportunity exploration.

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1. INTRODUCTION

Entrepreneurial technology ventures are an important source of new product opportunities and innovation (Cohen, Nelson, & Walsh, 2002; Shane, 2004). In particular, those ventures that create new technologies from basic research advances often reveal several potential market opportunities (Danneels, 2007; Shane, 2000). However, for each of these market opportunities generated by the new technology, there is uncertainty regarding the feasibility of the technology, the size of the applicable market, and the venture's ability to take the technology from the lab to the customer (Link & Ruhm, 2009). Faced with this technological and market uncertainty, high technology ventures have the fundamental challenge of deciding which market opportunity to pursue to maximize economic value for both the venture and consumers (Jolly, 1997; Kor, Mahoney, & Michael, 2007).

Entrepreneurship and innovation literature suggests that due to the uncertainty in linking the technology to the market, high-technology ventures can increase their chances of survival and growth by identifying multiple opportunities (Gruber, MacMillan, & Thompson, 2008, 2013). Identifying more than one market outlet can even help companies produce a more innovative product (Shepherd & DeTienne, 2005). Similarly, several innovation approaches assert that firms should invest time and money in exploring several technological opportunities to find a "winner" (McGrath, 1999; McGrath & MacMillan, 2009). Innovating firms can increase the likelihood of successful market entry by pursuing multiple market opportunities (Katila & Ahuja, 2002; Leiponen & Helfat, 2010). This impact is non-trivial for entrepreneurial ventures, as early strategic choices made by ventures leave a lasting imprint on organizational structure, strategy and performance (Beckman, Burton, & O'Reilly, 2007; Fern, Cardinal, & O'Neill, 2012). Despite the benefits of identifying multiple opportunities, managers and founders tend to "satisfice", only searching for alternatives until one meets their aspiration levels and accepting the first that does so (Simon, 1947). For high-technology ventures especially, the identification of multiple market opportunities is fairly uncommon (Shane, 2000), though it can be enhanced by the founders' knowledge and experiences (Gruber, MacMillan, & Thompson, 2012; Gruber et al., 2013).

While much is already known about the importance of identifying multiple market opportunities, little is known about how these companies actually explore these opportunities. This study distinguishes between the cognitive search process referred to by opportunity identification and opportunity exploration, which involves experiential search employed by high-technology ventures in technology commercialization (Cyert & March, 1963; Gavetti & Levinthal, 2000; Nelson & Winter, 1982). It is unclear what factors influence a new venture to explore multiple market opportunities, especially when this exploration is quite costly.

Exploring several market opportunities should increase a venture's likelihood of finding an application that is both technologically feasible and that has potential to serve a market of sufficient size to merit commercialization. However, organizations rarely explore more than one opportunity (Bromiley, 2009), as the evaluation of other opportunities is a costly process. This is especially the case for entrepreneurial ventures emerging from universities, where the new technology must go through a long, uncertain and costly development process in a particular market before commercialization can take place (Jensen & Thursby, 2001). The decision to explore market opportunities under uncertainty and temporal and financial constraints is dictated by the members of the founding team. What configuration of the founding team will enable the venture to explore a greater number of market opportunities, so as to construct a superior choice set?

This paper explores the configuration and behaviors of founding teams, in particular the way they make economic decisions about which opportunities to explore (Cyert & March, 1963). These decisions are fraught with uncertainty; organizational learning and routines cannot easily be brought to bear when deciding which market opportunities to explore. Because the decision of which application of the technology to pursue cannot be solved "off-line" (Gavetti & Levinthal, 2000), boundedly rational firms engage in problemistic search for a solution according to the selective attention given to the problem by managers (Cyert & March, 1963; Kaplan, 2008; Washburn & Bromiley, 2012). The amount of search performed by the firm is therefore tied to the attention level of the decision-makers (Ocasio, 2011; Simon, 1947), and is inherently biased by their incentives, past knowledge and experience.

We argue that a venture's level of opportunity exploration will be influenced by the knowledge and experiences of each of the members of the founding team. Moreover, because the attentional capacity of humans is limited, the roles and incentives held by the decision-makers of the firm should also direct firm behavior (Simon, 1947). In university technology ventures, science and engineering professors, often with graduate students and industry scientists, launch new ventures to commercialize the very technology they have been studying at their university laboratories. The roles played by these scientific founders are often guided by the roles and routines imported from their work in the university (Miner, Gong, Baker, & O'Toole, 2011).

This article suggests that opportunity exploration is a function of executive attention, which will be influenced not only by the founder's stock of prior knowledge and experience, but also by the roles and incentives of the different members of a founding team. Despite its importance, little extant research sheds light on the way a founding team identifies and explores markets in which the technology can create value for customers (Kor et al., 2007). The range of potential market applications for the technology is subjective and must be imagined, created, and discovered by managers over time (Cyert & March, 1963; Danneels, 2007; Foss, Klein, Kor, & Mahoney, 2008). Findings in entrepreneurial and innovation literature suggest that firm executives are primed to identify and explore those market opportunities that relate to their existing knowledge sets and experience (Cohen & Levinthal, 1990; Kaplan, 2008; Leiponen & Helfat, 2010; Shane, 2000; Shane & Venkataraman, 2000).

Drawing from economics and management research, this article develops hypotheses to predict how differing roles of founder-scientists will affect the high-technology venture's opportunity exploration, while taking into account the impact of the founding team's knowledge and experience on the strategic choice of opportunity exploration (Fern et al., 2012; Ucbasaran, Westhead, & Wright, 2009). Specifically, what is the effect of different *combinations* of experience, as well as the organizational roles filled by the team, on the venture's propensity to explore alternative market opportunities?

I test my hypotheses in the context of university spin-off ventures commercializing an invention from 1983 to 2012. This setting provides an ideal setting for the process of opportunity exploration, as each new invention has several technological applications or potential business opportunities which reduce potential endogeneity concerns found in literature on opportunity identification (Gruber et al., 2008; Shane, 2000).[1] In the process of commercializing scientific inventions, each application undergoes a vetting period before settling on a specific market opportunity. The vetting process for each application introduces a tradeoff for the new ventures: exploring multiple market opportunities may increase the likelihood of finding one that will succeed, but the exploration of each additional market opportunity introduces attentional, temporal and financial costs (Murray & Tripsas, 2004). Decisions about which markets to explore

[1] Interviews with technology transfer officers suggest that these ventures commercialize technologies that are more general, as the officers prefer to license the technology to established firms whenever possible. These technologies are composed of more basic, tacit knowledge, often backed by a number of patents; when they are not licensed to other firms, or if they are narrowly licensed, the academic scientist then has the option to consider founding a new venture to translate the technology to the market.

are made by the founding team—in this case, academic scientists at the professor, graduate and undergraduate level, in addition to the occasional industry scientist.

This study extends prior research on opportunity recognition (i.e., Gruber et al., 2013) in several ways. First, this work focuses only on high-technology firms commercializing inventions from universities as compared to studies covering more general technology ventures. The current sample is one where each technology developed has many potential commercial applications, which are difficult to verify without considerable time and cost. To control for the drawn-out nature of the vetting process for each potential technological application, this study also observes the opportunity exploration behavior of the new venture and distinguishes between types of opportunities, rather than merely measuring how many opportunities were identified, (Shane, 2012). This work goes beyond prior studies by exploring how scientific founders decide how much time, energy and effort to bring to bear testing different applications before "placing a bet" on one[2]. Finally, this study goes beyond founder experience to examine how the roles played by the different members of the founding team affect the number of market entry options explored.

2. **THEORETICAL BACKGROUND: Linking New Technologies to Market Opportunities**

Organizations face difficult decisions when deciding how their resources, technologies, or inventions, can create value for consumers. These difficult decisions require management attention, as they cannot be easily addressed by importing routines (Cyert & March, 1963; Nelson & Winter, 1982; Ocasio, 2011). A central tenet of the Penrosian approach to resources explains this difficulty, stipulating that a single resource, when used in novel ways or in unique combinations, can provide a *different* service or *set* of services, which can create value for customers in various product market domains (Penrose, 1959). The range of potential services from these resources is limited by the subjective market opportunity set of managers, which is not "a given," but must be imagined, created, and discovered by managers over time (Cyert & March, 1963; Danneels, 2007; Foss et al., 2008).

Technological inventions are appropriate applications of this theory, as market opportunities arising from an invention are not self-evident, but must instead be identified by firm founders through an experiential search process. Indeed, each of these developing opportunities are inherently "equivocal" (Weick, 1990: 2). That is, they require founders to make sense of them and

[2] This is different from the question typically studied in entrepreneurship literature of would-be founders who discover or create an opportunity might they then form a firm to pursue.

decide how to develop them. Unfortunately, managers have limited foresight into which market opportunity will prove successful. In the case of a new invention, managers do not know, ex ante, which potential products or services can be generated from an invention and which markets would be best suited for their product (Afuah, 2002; Danneels, 2007; Dougherty, 1992). Even highly successful inventors acknowledge their inability to predict which of their inventions would lead to a market breakthrough, and in which markets they would have an impact (Schwartz, 2004).

In the context of high-technology ventures commercializing a technological invention, the difficulty of this experiential process suggests that new ventures must do more than simply identify opportunities through local search to commercialize their technology. Indeed, high-technology ventures commercializing inventions often engage in costly exploration over several years before the link between technology and market can be forged (Jensen & Thursby, 2001). Interviews with Technology Transfer Office personnel at a large R1 Institution indicate that this is especially the case for technologies emerging from universities, as the more uncertain projects are more likely to be commercialized via venture rather than license[3]. Thus, in the context of university start-ups, the sense-making process goes beyond Kirzner's (1973) notion of opportunity recognition and extends to opportunity development, which requires a great deal of time, money and attention (Weick, 1990). Thus, research focusing on opportunity identification cannot adequately capture the process that ventures go through when choosing which opportunities to pursue.

The concept of opportunity exploration may be more appropriate to capture the uncertain, costly search process employed by high-technology ventures in technology commercialization. A key element of opportunity exploration is that it is difficult, and even hazardous, to explore multiple opportunities in parallel (Murray & Tripsas, 2004). A useful analogy is that of beach-goers who comb the sand in search of buried treasure[4]. The initial ping of the metal detector stops the scavenger from further surface-level search; he or she must then decide whether to take the time to dig through the sand to find the potential treasure underneath or continue searching for a better location. This analogy describes the process of opportunity exploration, where the invention serves as a crude metal detector, leading to potentially value-creating market opportunities in high-technology markets. As these

[3] Informal discussions between author and various technology transfer officers in the University of Illinois and University of California systems, March 2014.

[4] The initial search for applications corresponds to the search stage of the behavioral theory of the firm, while the testing process belongs to the decision-making stage of the behavioral theory of the firm, as managers must consciously decide whether to continue development or test a different application.

opportunities consist of both technological and market uncertainty, entrepreneurs must "dig down" in focused exploration to test the feasibility of the technology and the market. Upon initial *recognition* (ping!) of a potential market opportunity, firm founders must decide whether to commit resources to exploring the opportunity, or continue the search for other (potential superior) market opportunities. Thus, this exploration process allows ventures to find and pursue opportunities that are more likely to be of higher economic value than ventures that simply identify opportunities.

The founding team and technological resources determine how a new high-technology venture will explore market opportunities. The current context of technology-based ventures enables us to focus on the differences among the founding team, as the "basic" nature of the underlying technologies warrants several potential market opportunities. Founders process information about the firm and decide how to channel and distribute their attention on different market opportunities (Simon, 1947). In deciding how to direct their attention, founders rely on their knowledge sets, incentives, and the roles played by each member of the founding team (Kaplan, 2008; Simon, 1947).

Thus, the composition of the founding team in high-technology ventures profoundly impacts this market exploration process, as the knowledge and past experience of the founding team constrains these choices in high-technology ventures (Beckman, 2006; Fern et al., 2012). Because the attentional capacity of humans is limited, the assignment of individuals to organizational roles serves as key a driver in pursuing organizational objectives (Simon, 1947). The open question for ventures commercializing new technologies is what configuration of the founding team will enable the venture to explore a greater number of ideas, so as to construct a superior choice set? Specifically, what is the effect of different *combinations* of experience, as well as the organizational roles filled by the team, on the venture's ability to generate a choice set of alternative market opportunities? The following section explores each of these factors in more detail.

3. HYPOTHESIS DEVELOPMENT

The hypotheses developed in the current paper focus on two critical yet hitherto unaddressed questions. First, how does past experience among founders influence the opportunity exploration behavior of the venture? Past research reveals that entrepreneurs often pursue the first market opportunity they identify, based on their past knowledge (Shane, 2000). Founding teams with higher levels of knowledge diversification, however, tend to identify a larger number of opportunities prior to technology commercialization (Gruber et al., 2008; Gruber et al., 2012). For high-technology ventures operating under limited attentional capacity and intense financial and temporal constraints, it remains to be seen whether the costly process of opportunity exploration will correspond with the aforementioned observations linking founders' experience to the identification of multiple opportunities.

Second, what is the relationship between pre-entry market opportunity development and the scientific makeup of the founding team? Economic and management theory on scientists suggests that the scientific routines inherited by academic scientists create non-trivial differences vis-à-vis founders with industry experience in their approaches to technology development (Miner et al., 2011). Due to the threat of routine rigidity to those scientists of longer tenure (Gilbert, 2005), I then examine how the exploratory behavioral differences observed in the high-technology ventures can be explained by the presence of both novice and veteran scientific founders in the new venture.

3.1 Knowledge and Experience in Opportunity Exploration

In situations where there is no predetermined schema to achieve goals, as in the case of non-routine activities such as technology development, executive attention guides the firm decision-making process (Fernandez-Duque, Baird, & Posner, 2000; Simon, 1947). In uncertain situations, organizational attention is largely governed by the knowledge and experience of the executives (Gavetti, Levinthal, & Rivkin, 2005; Kaplan & Tripsas, 2008). Executive knowledge plays a particularly important role in early firm strategy formation and outcomes (Beckman & Burton, 2008; Penrose, 1959).

One key source of knowledge for the high-technology venture is prior entrepreneurial experience. Because entrepreneurial experience has many tacit components that are learned by doing, it provides a particular type of knowledge that cannot be acquired easily through other types of learning (Delmar & Shane, 2006). Founders with prior entrepreneurial experience should therefore possess a better understanding of the entrepreneurial process. As almost all entrepreneurs modify their initial strategy at least once prior to market entry (Bhidé, 2000), entrepreneurial experience should increase the founders' attention outwards in the search for better opportunities.

Entrepreneurial experience should also affect the extent to which ventures explore opportunities. In general, individuals operating under ambiguous environments tend to be overoptimistic (Camerer & Lovallo, 1999). This overconfidence is often amplified in entrepreneurs (Busenitz & Barney, 1997) as new ventures do not have established decision-making routines or past data to help founders manage complexity. Instead, entrepreneurs rely on simplifying biases and heuristics to make decisions in the face of uncertainty (Bercovitz, de Figueiredo, & Teece, 1997; Nelson & Winter, 1982). Prior entrepreneurial experience may motivate the venture to overcome the natural tendency to be overoptimistic by increasing the venture's aspiration levels, which will cause the firm to continue the search for a solution and engage in a higher level of opportunity exploration. This line of reasoning is consistent with that of Penrose (1959: 37), who suggested that entrepreneurial judgment involves more than a combination of personal qualities, but "is closely related to the organization of information-gathering and consulting facilities within a firm."

Those founders with past entrepreneurial experience indeed may also have developed superior routines that facilitate the identification of opportunities (Baron & Ensley, 2006) or allow them to notice patterns that others have overlooked (Gaglio, 2004), which may explain why ventures with prior entrepreneurial experience identify more opportunities than others (Gruber et al., 2008; Ucbasaran et al., 2009). As founders consistently import routines from their prior experience (Miner et al., 2011), one routine imported may be related to the evaluation and pursuit of opportunities (Alvarez & Busenitz, 2001). It may be that this experience leads to a routine of "chronic" alertness for new opportunities (Gaglio & Katz, 2001), that will cause those ventures with prior entrepreneurial experience to engage in the costly process of opportunity exploration prior to commercialization.

In sum, this behavioral tendency matches the strategic moves of serial entrepreneurs in general, who identify multiple business opportunities before they decide on which one is better to pursue (Gruber et al., 2008, 2013; Ucbasaran et al., 2009). However, extant work does not tell us whether high-technology firms engage in costly opportunity exploration. Extending earlier research, we argue that prior entrepreneurial experience in the founding team will lead to increased opportunity exploration.

H1: High-technology ventures which have a serial entrepreneur as part of the founding team will engage in more opportunity exploration.

Besides being influenced by prior entrepreneurial knowledge, a venture's exploratory behavior will be influenced by the breadth of the venture's technical knowledge. In linking technologies to markets, founding team members' knowledge shapes the perceived relevancy of received information, directing decision-maker's attention toward certain aspects of the problem, which drives organizational search (Gavetti, 2005). Thus, a broad technical knowledge set may enable ventures to view the decision problem in a broader light, and perhaps enable the venture to overcome the bias towards filtering information that matches one's existing knowledge set (Kaplan & Tripsas, 2008)[5]. A related literature on innovations maintains that knowledge breadth is critically important when creating novel products and services, as similar knowledge sets lead to similar problem-solving techniques, which constrain team's ability to explore opportunities outside their area of expertise (Bercovitz & Feldman, 2011; Fleming, 2001; Fleming, Mingo, & Chen, 2007). While few founders exhibit knowledge of any choices other than the opportunity they pursue (Shane, 2000), ventures that bring together a more diverse set of knowledge should have greater ability to leverage the expertise of each individual team member and apply a wider range of information to the creative process of opportunity development (Cohen & Levinthal, 1990; Dahlin, Weingart, & Hinds, 2005).

Moving beyond ability, founding teams composed of members with various knowledge backgrounds may also have more incentive to explore more opportunities, and therefore direct more attention towards opportunity exploration. As individual's information gathering and processing behavior evolves from past experiences, ventures with more diverse knowledge sets may experience more conflict (as each member should be more likely to advocate distinct market applications), leading to increased search before settling on a market application to pursue (Cyert & March, 1963). Conflict among which potential market application to pursue should lead to an increase in the number and variety of solutions that are generated (Eisenhardt, 1989). Enhanced conflict within the founding team should in turn increase the duration of the opportunity exploration phase, as collaborative selection will be more rigorous than lone selection (Singh & Fleming, 2010). Following this logic, one can expect a positive relationship between breadth of the founding team's knowledge set and the amount of opportunity evaluation. This theoretical reasoning leads to the following hypothesis:

H2: High-technology ventures with a founding team composed of scientists with a multi-disciplinary knowledge set will engage in more opportunity exploration.

Similarly, ventures led by scientists with both academic and industry experience may also explore more opportunities. Because the entrepreneur's subjective perceptions of the market shape entrepreneurial ideas about what the venture can and cannot do with its technological resources, new ventures with greater levels of industry experience should be able to pay attention to and therefore

[5] Thus, the bias towards filtering information that matches one's existing knowledge set may occur precisely because domain insiders have deep knowledge of their context (or technological approach), augmenting their ability to recognize and react to information that enhances their own existing competencies while filtering out information about competence-destroying changes (Christensen & Bower, 1996; Tripsas & Gavetti, 2000).

identify more market opportunities for their technology (Fern et al., 2012). Greater diversity of academic and industry experience should increase the number of available solutions to the venture, which in turn enhances innovative outcomes (e.g., McGrath, 1999).

While general innovation theory suggests that greater diversity in experience should lead to increased opportunity exploration, there is reason to believe that the same effect might not hold for the scientist-led university venture. In contrast with the scientific method of pursuing multiple research paths simultaneously, business objectives tend to be focused on milestones, such as quickly exploiting a single application (Samsom & Gurdon, 1993). As scientists have a lower inclination to deal with market-related issues than those with industry experience, technology-driven ventures often experience discord between business and scientific incentives and behaviors (Dougherty, 1992; Miner et al., 2011). Organizations can only partially resolve conflict among members' goals by attending to them sequentially (Cyert & March, 1963). Therefore, high-technology ventures led by founders with both industry and science experience may perform less opportunity exploration in order to resolve conflicting motivations among founders.

This contrast is highlighted by recent research, which reveals that those emerging scientists who prefer industrial employment show a weaker "taste for science," a greater concern for salary and a stronger interest in downstream work compared to those who prefer an academic career (Roach & Sauermann, 2010). Experimenting with multiple potential market opportunities involves both direct and indirect opportunity costs to ventures, requiring that founders allocate time (Miner et al., 2011), attention (Gifford, 1992) and money away from other activities to pursue that behavior. Thus, high-technology ventures composed of scientific founders working in both industry and academia may be *less* inclined to invest the additional time in exploring multiple market outlets for the venture's technology due to the conflicting goals of industry and scientific members of the venture.

Additionally, industry experience may expose scientists to a larger array of market opportunities, leading ventures with industry experience to more quickly explore market opportunities than scientist-only ventures (Franklin, Wright, & Lockett, 2001). Ventures tend to fixate onto the opportunities already identified, (Ronstadt, 1989; Shane, 2000), encouraging those ventures with industry partners to forgo the experimentation stage. Indeed, as past experience in industry contributes to the competence of the venture in sensing (Gruber et al., 2013) and seizing (Kor, 2003) new growth opportunities, those ventures with greater levels of industry experience may assess fewer opportunities than the ventures with lower levels of industry experience. This theoretical reasoning leads to the following hypothesis:

H3: High-technology ventures with a founding team composed of scientists with industry experience will engage in less opportunity exploration.

3.2 The Role of Expertise Opportunity Exploration

In the context of high-technology university ventures, faculty founders represent both deep domain knowledge and experience. Research on domain experts, defined as individuals with deep domain knowledge and experience, suggests that they are more capable of understanding the underpinning structural features of a problem (Ericsson & Charness, 1994) and therefore have superior pattern recognition skills, can better anticipate the future and generate more robust solution maps (Furr, Cavarretta, & Garg, 2012). As a result, individuals with extensive domain experience may have a greater ability to recognize and integrate information, such as signals of other technological applications (Cohen & Levinthal, 1990; Eisenhardt, Furr, & Bingham, 2010). Thus, ventures composed of university faculty, should, due to their considerable expertise, have the ability to engage in more opportunity exploration, especially in unpredictable markets, where the technological landscape has considerable variation.

Although university faculty are clearly scientific experts, we need to take a closer look at the mechanisms underlying their behavior as it relates to founding an entrepreneurial venture. The critical role of technical knowledge has led research in high-technology ventures to focus primarily on the impact of star faculty founders (i.e., Fuller & Rothaermel, 2012; Murray , 2004). Indeed, science-based faculty founders have tacit knowledge that is critical in developing and marketing an invention. In addition to knowing how to write and receive grants for research funds, faculty are experts in their technological field, which counts much more than simply “a relevant graduate degree in either a related science or engineering discipline,” which is often the standard used for scientific expertise used in the literature (Hsu, 2007). Such depth of knowledge enables these faculty-founders to identify unique technical opportunities (Shane, 2000) above and beyond those provided by high levels of generalizable education.

On the other hand, two main arguments suggest that the scientific expertise held by faculty may limit the opportunity exploration of the venture. First, literature on scientists’ productivity indicates that the innovative behaviors of inventors changes over their life cycle (e.g., Levin & Stephan, 1991). Over time, expert scientists often focus their efforts toward a particular technological domain due to financial incentives provided to specialists, which narrows their recombinatory abilities (Leahey, 2006). In addition, the knowledge acquired by an inventor during her education, which guides her technological search behaviors, may have diminishing relevance for her technological recombination activities over time, adding to the difficulty of recombining technological knowledge across domains (Fleming & Sorenson, 2004). This effect might be compounded when crossing the domain from technological to business opportunities, as experts may become overly-tied to their own expertise and routines (Teece, 2007), especially in demanding job situations (Hambrick, Finkelstein, & Mooney, 2005). Thus, while the knowledge set of expert scientists is considerable, there is evidence that over time its generalizability will diminish, constraining the amount of business opportunity exploration.

In addition to a lower generalizability of knowledge, university ventures led by only faculty experts may also lack the requisite roles to engage in high levels of opportunity exploration. This paper follows the logic developed by the NSF[6] that there are two key roles needed in a new venture involved in the early technology development process: a principal scientific investigator and an entrepreneurial lead. The roles played by these scientific founders are often guided by the routines imported from their work in the university (Miner et al., 2011), making the jump from faculty to principal investigator very easy. It is much more difficult for university spin-offs to have a founder filling the role of entrepreneurial lead, however, as most faculty retain their employment (Hayter, 2011) and most firms are founded only by faculty (Ensley & Hmieleski, 2005). This homogeneity may lead to routine rigidity (Gilbert, 2005), where we may expect to see increased technological search in ventures led only by expert-faculty, but less opportunity exploration. In summary, while faculty-led ventures should have the ability to engage in opportunity exploration due to their considerable expertise, this evidence suggests that these ventures may have obstacles to overcome to explore multiple opportunities.

Two main arguments suggest that a key to overcoming knowledge and routine rigidity is to have knowledgeable yet inexperienced graduate students who are also founders. First, the decision to engage in effortful search is driven by the incentives of the decision-makers, in addition to their knowledge sets (March, 1994). [7] To shed further light on this issue, economic and management theory on scientists and innovation diffusion suggest several reasons why the incentives of the scientists will have a significant

[6] Read more about the NSF's I-Corps program here: http://www.nsf.gov/news/special_reports/i-corps/index.jsp
[7] Other literatures support this paragraph's logic; creativity research suggests that besides knowledge, cognitive skills and abilities, intrinsic motivation is also fundamental to achieving creative outcomes (Amabile, 1996).

effect on the venture exploratory behavior. First, it is not clear that the financial motivations from entrepreneurship provide a significant motivation for successful faculty scientists (O'Gorman, Byrne, & Pandya, 2008). Experimental evidence suggests that domain experts demonstrate less effort when financial rewards are on the line (Shepherd & DeTienne, 2005). This may explain why one of the major challenges for technology-transfer officers in technology-to-market linking process is incentivizing faculty-inventors to continue to develop inventions beyond the proof of concept stage (Jensen & Thursby, 2001). The lack of a strong link between financial incentives and effort may also explain why faculty, who are expert scientists, are strongly associated with increases in knowledge production (Zucker, Darby, & Armstrong, 2002), but highly-motivated graduate students play a more significant role in pushing technology towards commercialization (Carayol & Matt, 2004; Stephan, 2012). Without an established career in academia to fall back on in case of a failed venture, graduate students should have more incentive to explore more business opportunities.

Second, there is recent evidence that graduate students who join new ventures are different from those that become academics. Significantly, those Ph.D. graduates who prefer start-up employment rate their highest motivators as an interest in responsibility, intellectual challenge and applied research and development, while Ph.D. graduates interested in academia did *not* rate these attributes as motivating (Roach & Sauermann, 2010). When decision-makers search, they allocate attention to certain aspects of the environment and ignore others. Attention is a cognitive process that involves the noticing, interpretation, and focusing of time and effort on the acquisition of knowledge and information (Kahneman, 1973). The principles above suggest that scientists tend to sort themselves into different career trajectories (Agarwal & Ohyama, 2013) based on their preferred behaviors. Graduate students who have self-selected into founding a start-up may be more likely to devote more attention to the task of downstream technology development, due to a more focused knowledge set and commercialization incentives, than faculty.

A representative example of a thus-composed high-technology venture is Alphabet Energy, whose founding team consisted of a UC-Berkeley Chemistry professor and a Material Science Ph.D. student. Alphabet Energy applies a unidirectional nanotechnology developed in Dr. Peidong Yang's lab to adapt silicon into an efficient thermoelectric material for waste-heat recovery. Matthew Scullin, working at the Lawrence Berkeley National Laboratory during his Ph.D. program at UC-Berkeley, was part of the team that applied this (and other technologies) to use silicon as an efficient thermoelectric material. The two decided to get together to found a company, with Matthew as CEO and Peidong as

Scientific Advisor, coupling Dr. Yang's expertise in nanotechnology with Matthew's applied knowledge and ability to think outside the box. At this time, Matthew began working full-time for Alphabet Energy while Dr. Yang remained at the university. Similar to the oft-cited MIT example of 3D-printing, Alphabet Energy's underpinning technology has many applications in optics and electronics, whose idea-to-market path differs significantly from the clean technology path the inventors ultimately took to commercialize the technology[8]. During the development of the clean technology application, Alphabet Energy explored two other opportunities with the Department of Defense to develop self-powered equipment and to increase waste heat recovery in military aircraft. Ultimately, Alphabet Energy decided to "shelve" these two applications until after developing the current application further, as it had the highest market projections. The next year that application received $12 million in venture capital. This exploration was done prior to searching for venture capital, as venture capitalists desire a clear market direction. The importance of mapping out the various opportunities prior to commercialization is highlighted by this example, as each approach can require years of focused effort before venture capitalists are involved.

In light of these arguments, ventures composed of both faculty and graduate students should have advantages compared to ventures composed solely of faculty experts or those composed solely of graduate students, with respect to their knowledge-combining disposition and capabilities:

H4b: High-technology ventures with mixed levels of scientific expertise will engage in more opportunity exploration than ventures composed of solely experts.

4. Research Design

4.1 Data

Examining these hypotheses requires data about the founding members and opportunity exploration behavior of high-technology ventures. The key independent variables pertain to the education and experience of the founding team and the dependent variable is the number of SBIR (Small Business Innovation Research) grants awarded to these high-technology ventures, in addition to important technology-to-marking linking variables such as the technological industry and whether the

[8] For current press see: http://nanowires.berkeley.edu/index.php/research/interests/ ; http://www.businessweek.com/magazine/matt-scullin-power-recycler-09292011.html

technology was licensed from a university. Because no public data set offers the information required for this study, I contributed to a unique database[9] of all technology-based ventures created by university-affiliated personnel at six public research universities in the United States. This study examines 598 high-technology spin-offs from these six universities between the years 1983 and 2011.

4.1.1 Sample Construction

This database was intended to be a census (not a sample) of only de novo, high-technology university ventures in the six universities. To be recognized as de novo the firm could not be a spin-off from an existing firm or be a subsidiary or branch operation. Very small firms of just a few employees providing services or engaged in consulting were excluded from consideration, as were all exclusively retail establishments.

Importantly, the ventures had to be technology-based. This removed from consideration firms in apartment management along with small consulting firms established by university personnel. If the venture was, for example, writing software algorithms for larger firms, then it would be included. Also, internet website firms based on commerce (i.e., “Champaign Beer.com”) targeting the local region were excluded, as their purpose was only to sell a low-technology product. In contrast, software product spin-offs were included as were internet firms that grew to be large enough to have a significant web presence or receive venture capital. The reasons for these exclusions were to capture high-potential technology entrepreneurship and exclude firms such as those Wright et al. (2008) identifies as “life-style” firms.

Finally, to be classified as a university spin-off, a firm had to have been founded by at least one individual affiliated with the university during or immediately prior to establishing the spin-off. An attempt was made to identity the founders through web searches[10]. At the time of the firm's founding, the status of the founders’ relationship with the university was determined. This relationship was determined from the founder's biography, which was usually pulled from the internet. A firm founded by an individual who had other employment between the time they left the university and founded the

[9] This database was initially begun by Kenney and Patton (2011), then personally verified and extended by the author.
[10] If the founder or founders of a firm could not be identified, or if there was insufficient information to determine the employment background of the founder, these firms were not included in the database. The decision to focus on university spin-offs was made to control for differences between university and non-university spin-offs (Ensley & Hmieleski, 2006).

firm would not be classified as a spin-off[11]. Firms that were established based on a university technology license were excluded if no firm founder was affiliated with the university. An important reason for excluding such “license-only” firms is that examination of a number of these firms indicated that often they were established on the basis of a number of licenses from a variety of organizations, and so establishing a causal linkage between the firm formation and a particular university license is not self-evident. Due to the timeline of the dependent variable measure, firms founded before 1981 were also dropped from the analysis (n=35).

4.1.2 SBIR Grants

To test my theory, I sought a context which allowed me to identify specific opportunity exploration behavior of high-technology ventures. This article employs SBIR (Small Business Innovation Research) grant data as a proxy for opportunity exploration. Enacted in 1982, the SBIR program is a public program that provides grants to fund private sector R&D projects. It aims to help fulfill the government’s mission to enhance private sector R&D and by advancing innovation in the basic sciences for ventures in very early stages of product development. Companies often use SBIR to fund alternative development strategies, exploring technological options in parallel (Wessner, 2007). Indeed, the stated purpose is to enable ventures to “explore their technological potential.” As this measure has not often been used in management literature, I provide a more detailed explanation of SBIR awards and their history below.

SBIR provides awards in three phases. The purpose of Phase I awards is to assist businesses as they assess an idea’s scientific and commercial potential and feasibility. As the focus in this stage is on prototyping of developing proof of concept, the awards are normally capped at $100,000 (Link & Scott, 2010). [12] In this first phase, a proposal must address the potential for commercialization of the innovation and how it would ultimately lead to revenue generation. Organizations can apply for and win multiple Phase 1 awards, although competition for awards is strong.

Ventures face a tradeoff when considering whether or not to apply for a Phase 1 SBIR grant. The application process is arduous and uncertain, as proposals are usually peer-reviewed and must establish

[11] The time elapsed between the time an individual, usually a student, left the university and founded a spin-off was determined by the individual's biography. If this time period was 1 year or less, and there was no information indicating that the individual was employed in the interim, then it was classified as a university spin-off.
[12]See: http://grants.nih.gov/grants/funding/SBIRContract/PHS2008-1.pdf, p.1.

technical merit, feasibility and commercial potential of the invention.[13] Also, the financial capital awarded by these grants is fairly low, only allowing for small feasibility tests of the technology. In order to commercialize, high-technology firms usually require venture capital(Link & Ruhm, 2009). Significantly, a firm is excluded from applying for SBIR grants if they are >50% backed by venture capital funding. Finally, each application must be distinct from the last, moving laterally to explore a different direction for the invention, and are not a function of having won previously. The small financial amount of the awards, coupled with the difficult application process and the inability to receive venture capital fund, introduce significant costs for the new ventures. It is thus a strategic choice for a venture to choose to apply for one or more Phase 1 grants.

4.2.1 Dependent Variables *Number of Market Opportunities Identified*. This variable measures the number of Phase 1 SBIR grants using the same underlying technology to capture the number of market opportunities developed by high-technology ventures in linking their technology to the market. In finding appropriate measures of market opportunity development, the empirical measure must be both tied to the venture's underpinning resource base (Penrose, 1959), and—true to the notion of opportunity as subjective (Penrose, 1959: 41)—must be delineated from pure ideas or dreams (Short, Ketchen, Shook, & Ireland, 2010). That is, the proxy should have to be subject to some evaluative process before it can be labeled as an opportunity (Dimov, 2007).

I suggest that the measure of SBIR I grants received by the firm can reasonably proxy the concept of opportunity exploration. Because these technologies take years to develop past the patent or licensing stage (Jensen & Thursby, 2001), and it is difficult to find venture capital to support such basic research, these grants serve a fundamental role in exploring possible applications of the technology. As an example, consider a materials venture working with nano-fiber technology that, with the support of two Phase 1 SBIR grants, founders identified two separate market opportunities for the nascent venture: a filter additive to be used in water purification facilities and a regenerable air-filter for the use of HAZMAT suits. Taking the above arguments in consideration, this study does not presume that this measure covers the whole 'set' of exploration behaviors; however, the proxy is a superior measure in many respects to measures of opportunity identification used in current literature, which measure cognitive search (Gavetti & Levinthal, 2000) and limited by recall-bias and without an observable

[13] See: *http://www.sbir.gov/about/about-sbir*

measure; this measure captures experiential search by observing the strategic exploratory *behavior* of high-technology ventures.

4.2.3 Independent Variables. In order to adequately test the hypotheses of this paper, it was necessary to gather individual-level data on the early founders of the venture. For each venture, only data for individuals listed as "founders" were collected. There are currently no databases tracking these data, as many ventures are not 'on the radar' until after angel or venture capital funding has been awarded. By restricting the sample to founders, as opposed to the early top management team, I achieve greater consistency across the sample of ventures than have other studies in the measurement of entrepreneurial top management teams, as rounds of venture capital funding often accompany changes in the leadership structure of the venture (Wasserman, 2003). The status of founder was defined using company websites, personal profile pages, and news web searches, in addition to personal communication when necessary.

Entrepreneurial Experience Following the practice of extant research (Beckman et al., 2007), I coded a 1 for whether a venture had a founder with prior entrepreneurial experience.

Broad Knowledge Base. I coded whether the venture had a multi-disciplinary knowledge base as 1 if the team had scientific founders who worked in different academic departments, or, if one of them was graduate a student, if their Ph.D. was in a different field from that of the faculty founder. As the average number of founders was 2.2, this was not coded as a summation.

Industry Experience. As the majority of founders in the sample were either faculty members, staff researchers or graduate students, industry experience refers to the number of founders with industry experience who were unaffiliated with a university, but joined as a founder from another firm.

Expert & Mixed Scientific Teams. Faculty-founders have deep levels of tacit knowledge that is critical to the continuing development of an invention (Jensen & Thursby, 2001). Ventures' founding teams are classified as 'expert' if they contain only faculty scientists, while 'mixed' teams are composed of scientists at both the faculty and graduate student levels.

4.2.3 Controls.

Team Size. Because team size is an important indicator of the human capital available in a new venture, this study on market opportunity exploration controls for founding team size.

Licensing the Technology. Qualitative research suggests that ventures who license the technology from the university might have a slight advantage because the technology transfer office (TTO) can provide direction about potential market applications. It is thus important to control for whether the technology was licensed from the university, as this is the only observable measure of possible TTO assistance. This is coded as a dummy variable, 1 if the venture licensed the technology.

Industry. The resource requirements to develop new technologies and other factors vary across technological fields. To parcel out such variation, we included dummies to control for the technological fields represented in our study: IT & software (30% of the sample), biotechnology (24%), wireless and communications (12%), engineering and measurement instruments (22%) and others (12%) including nanotechnology, semiconductors, etc. These categories were defined using the description of the company given by the university or by the company's website. As the industry affects both strategy and performance, it is important to control for the technological background of the venture (Eesley, Hsu, & Roberts, 2014).

University. While scientists' proclivity to participate in university technology transfer is highly dependent upon individual attributes, those personal traits are conditioned by the local work environment (Bercovitz & Feldman, 2008). Universities vary, in terms of culture, in their attitude towards faculty and/or students participating in entrepreneurial behaviors. I therefore include a control for each university to mitigate the effect of the university on venture behavior.

4.3 Methods

The dependent variable takes on only nonnegative integer values and includes only zeroes and ones. Because ordinary least squares regression would lead to biased, inefficient, and inconsistent estimates in cases where the dependent variable is not normally distributed, we employed a negative binomial model to estimate the market opportunity counts of firms. I preferred the negative binomial model to Poisson regression because a likelihood ratio test of my data indicated over-dispersion; that is, the variance was greater than the mean (Hausman, Hall, & Griliches, 1984).

5. Empirical Results

5.1 Descriptive Results

The means, standard deviations, and correlations for all ventures in the sample are presented in Table 1.

Insert Table 1 Here

Correlations between dependent and independent variables, and among independent variables, are less than or equal to|0.42|, which is reasonably low, such that collinearity should not be a concern. I also computed the variance inflation measures for all variables, but only found small variance inflation factor values (<3). As Table 1 indicates, founders in our sample explored, on average, 1.78 market opportunities through the SBIR program. Figure 1 shows that the distribution of the market opportunity assessment variable is in line with that of similar studies (see Gruber et al., 2013), but also that firms are not likely to assess multiple market opportunities initially (Schwenk, 1984).

5.2 Multivariate Results

Results of the negative binomial regressions analyzing the market opportunity application of the technology are presented in Models 1-2 of Table 2. Because there is significant evidence of overdispersion (G^2=1117, p<.01), the negative binomial regression model is preferred to the Poisson regression model. The results shown in Table 2 are robust across the models, and the significant predictor variables significantly increase the explanatory power of our models, as measured by the difference in the log likelihoods and compared to a chi-square statistic with degrees of freedom equal to the number of newly added variables. To help shed more light on whether the high-technology venture applied for and received an SBIR award, I ran a probit model, with a dummy dependent variable, 1 for whether the venture was awarded a grant in Model 3.

Insert Table 2 Here

Hypothesis 1 predicted that high-technology ventures with entrepreneurial experience would explore a larger number of opportunities than ventures lacking this experience (β=.28, p>.1), but the results fail to support this hypothesis. Whether those high-technology ventures composed of scientists trained in distinct disciplines would explore a greater number of market opportunities than teams without this knowledge breadth is proposed in Hypothesis 2. The results show that high-technology ventures with broader knowledge training are able to explore more opportunities (β=.60, p<.05). Hypothesis 3 proposed that the addition of an industry-trained scientist into a science-based new venture has a detrimental effect on market opportunity exploration. Even after controlling for the differences across technological fields using the technological field dummies, the estimates provided in Model 2 reveal that the coefficient of the ratio variable *industry experience* is negative and significant (β=-1.00, p<.05). Hence, I claim support for H3. Hypothesis 4 predicted that high-technology ventures composed of experts and non-experts would explore a larger number of market opportunities than those composed of only experts. While the effects of both expert-only (β=.43, p<.05). and expert with non-expert (β=.77, p<.01) ventures are positive and significant, and there is an apparent difference in size of the coefficients, given the nonlinear nature of my model, it is important to note that the estimated coefficients do not represent marginal effects, making an interpretation of the results—except for the direction of an effect—difficult (Hoetker, 2007).

As a robustness check, I performed a probit estimation utilizing the dummy *awarded SBIR grant* as a dependent measure. While the results are mostly consistent, in the case of industry experience and an all-expert team, the results do not hold.

6. Discussion

Because decisions about which market opportunities to pursue are so crucial to the success of high-technology ventures, it is important to better understand the behavioral drivers underlying these decisions. In particular, I consider how the composition of the founding team influences market exploration. Prior research indicates the strategic importance of *identifying* multiple opportunities prior to market entry (i.e., Gruber et al., 2008; 2013), and finds that prior experience plays a significant role in this identification. While previous research has focused largely on market identification, we focus on market exploration to account for the considerable effort and strategic tradeoffs involved in exploring these opportunities prior to commercialization efforts. Because the decision of which market opportunities to explore is dictated largely by the members of the founding team, I attempt to unpack what guides executive attention and exploration of market opportunities.

This paper offers a look into the black box of decision-making under uncertainty by attempting to unpack what guides executive attention. While routines develop to influence firm behavior under standard operating conditions (Cyert & March, 1963; Nelson & Winter, 1982), discontinuities arising in the face of non-routine events (i.e., regarding technologies, markets and competition) confront executives with limited attentional capacity to explore all of their ramification (Ocasio, 2011). As the decision to explore technologies under considerable uncertainty is dictated by those individuals at the helm, a look into early technology-based ventures provides a more nuanced view of this process than a study on larger, established firms

Specifically, this work suggests that there are benefits to including heterogeneous levels of expertise in the founding team of the high-technology venture (see Hypothesis 4). This finding leads to further questions, as it is yet to be seen what types of teams will be able to take the technology further downstream. This finding is also in line with recent work on the preferences and initial career paths taken by graduating scientists (Roach & Sauermann, 2010). There is room for future research exploring the roles and motivations of non-expert scientists in technology commercialization. As technology-transfer experts report problems with university scientists to develop the downstream applications of a technology (Jensen & Thursby, 2001), this may prove to be a key to the technology-to-market linking problem.

Regarding the role of industry experience, this paper suggests that combining industry experience with scientific experience may have a negative effect on opportunity exploration (see Hypothesis 3). Specifically, this work finds that high-technology ventures with industry-trained scientists explore less than teams without this industry experience. This is worthy of note, considering that ventures with high levels of industry experience have been found to identify a greater number of narrowly-focused opportunities (Gruber et al., 2013). Future research should look more into this relationship on the development of the high-technology venture as it grows over time.

The findings also add to our knowledge on the effects of prior entrepreneurial experience, as this experience is not found to lead to more or less opportunity exploration (see Hypothesis 1). Previous literature suggests that this experience leads to the identification of more opportunities prior to entry (e.g., Gruber et al., 2008). My results, however, show that in settings where the technological resource requires significant development prior to opportunity exploitation, entrepreneurial experience does not lead to a marked increase in opportunity exploration. Recent findings show that prior start-up experience decreases the rate of both VC and going public (Beckman et al., 2007). It could be the high-technology ventures with *successful* experience may operate under the illusion of control, and may thus overestimate their knowledge of the market, precluding the exploration of opportunities. Future research may, therefore, examine the potentially different behaviors between entrepreneurs who have had successful companies (defined as IPO), and those who solely have entrepreneurial experience, due to this bias. Another mechanism behind the finding could be that serial entrepreneurs also acquire an improved “sensing” ability, which doesn’t require the same level of exploration as novice entrepreneurs.

A primary contribution of this work is an emergent notion about how founding team composition affects early venture behavior in the process of commercialization. While opportunity identification and exploration lie at the heart of the entrepreneurial process (Shane & Venkataraman, 2000), it has only recently been acknowledged in the literature (e.g., Gruber et al., 2008) and little agreement exists about the definition and nature of opportunities (Short et al., 2010). Whether the opportunity is "discovered" or "created", emerging technologies must go through a rigorous and costly process prior to resolving uncertainty regarding whether the technological application be viable for that specific market opportunity. This process is much more like combing a beach for gold; initial scientific measurements suggest where pockets of gold may lie, but a significant amount of work, and the opportunity cost of forgoing other opportunities, must first go into developing the "worksite" before it can be determined with any certainty whether gold lies in the region. Opportunity research will be enriched if more studies will take into account the difference between identifying and exploring innovative opportunities and apply search and decision-making theory to these behaviors.

This paper also contributes to the behavioral theory of the firm by focusing attention on the initial growth of the firm. Organizational performance, in this case, is that of the initial invention as it is developed for the market. This paper builds this theory by stipulating that initial problemistic search is in part driven by the knowledge sets, incentives and roles played by the founders. As this early search process has lasting implications for the firm, this is an area of the behavioral theory of the firm worth developing.

6.1 Limitations

In interpreting the results of this study, certain limitations must be kept in mind. First, because we cannot employ experimental data, various selection effects may be at work. In particular, certain technological breakthroughs may give rise to potentially greater number of market opportunities than others. While there is certainly heterogeneity in the technologies, in this respect the context of the study partially alleviates these concerns. The sample consists solely of technology-based university spin-offs, founded from more basic research than the typical "high-technology" venture. This is especially helpful for potential selection bias, as each firm in the sample would have had (at the least) several potential market opportunities to choose from.

Second, our study is largely based on whether firms receive SBIR grants. As we cannot observe the applications, this is certainly a worry that this measure is picking up a different effect. We must therefore assume that there is an equal ratio between SBIR applications and awards across ventures. Again, the context partially alleviates these concerns, as most university technology-transfer is performed by tenured, grant-receiving faculty in the engineering and science fields, who we can assume have attained a certain level of grant-receiving ability. In addition, the low dollar amount of SBIR grants puts them in the bootstrapping phase of venture funding, wherein ventures do a significant amount of search (Bhidé, 2000). The other two most likely source of funding—government grants and venture capital—are unlikely to fit this method of search, as government grants strive for improving the underlying technology, and venture capital promotes a quick drive to the market (Murray & Tripsas, 2004).

6.2 Conclusion

High-technology ventures must make the profound organizational decision of which market to pursue, and firms can make this decision more successfully by exploring several potentials before seeking commercialization. Against a background of sparse prior research, this study contributes to the recent discussion on the technology-to-market linking problem for new high-technology ventures, and produces results that have novel implications for the strategy, entrepreneurship, and innovation literatures. This research provides an observable measure of initial venture exploration, without respondent bias, which has been lacking in the literature (Dimov, 2007; Short et al., 2010). It also recommends that founding teams be made up of both diverse knowledge sets and scientific expertise so that appropriate attention can be given to explore opportunities prior to commercialization. Given the financial and attentional constraints faced by university entrepreneurs, and the low rate of commercialization, the decision to explore opportunities prior to commercialization is as important, if not more important, than the simple decision for faculty to launch a new venture.

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Figure 1

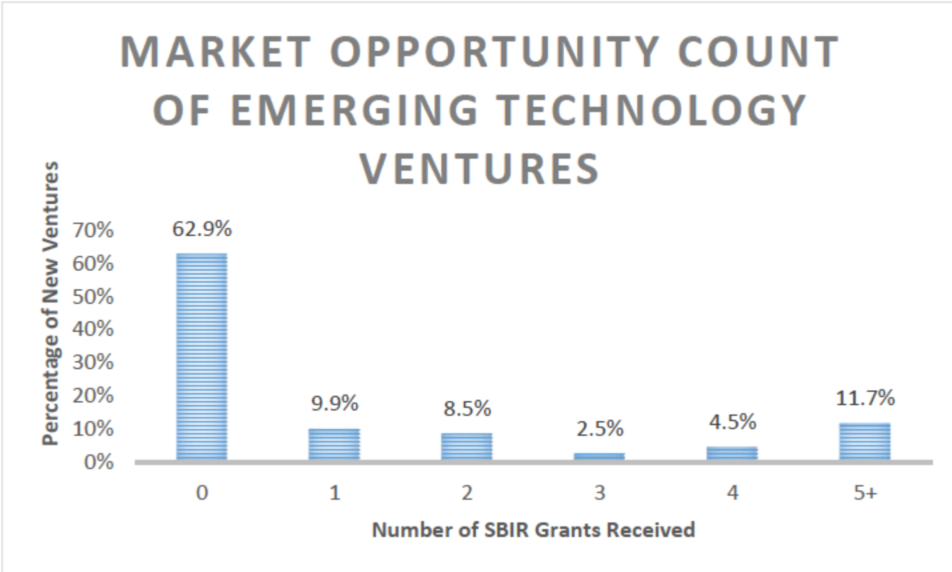
MARKET OPPORTUNITY COUNT OF EMERGING TECHNOLOGY VENTURES
Percentage of New Ventures
70%
60%
50%
40%
30%
20%
10%
0%
62.9%
9.9%
8.5%
2.5%
4.5%
11.7%
0
1
2
3
4
5+
Number of SBIR Grants Received

Table 1

Descriptive Statistics and Correlation Matrix

	Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	>1 SBIR	0.37	0.48	1.00															
2	# SBIR	1.78	3.91	0.59	1.00														
3	Serial Entrepreneur	0.17	0.37	0.00	-0.07	1.00													
4	Industry Experience	0.14	0.23	-0.08	-0.06	0.42	1.00												
5	Knowledge-Breadth	0.14	0.34	0.21	0.09	0.07	-0.04	1.00											
6	All-Expert Team	0.44	0.50	0.07	0.07	0.01	0.09	-0.07	1.00										
7	Mixed Team	0.13	0.33	0.15	0.13	0.03	-0.07	0.16	-0.33	1.00									
8	Licensed Technology	0.45	0.50	0.24	0.17	0.02	-0.03	0.04	0.16	0.01	1.00								
9	# Founders	2.18	1.13	-0.01	-0.02	0.32	0.30	0.25	-0.29	0.32	0.00	1.00							
10	Undergraduate	0.04	0.20	-0.09	-0.06	-0.07	-0.13	-0.06	-0.18	-0.08	-0.14	-0.05	1.00						
11	Age	15.14	9.62	0.00	0.06	-0.13	-0.07	-0.07	0.04	-0.06	-0.20	-0.13	0.06	1.00					
12	Tech: Software/EE	0.30	0.46	-0.33	-0.21	0.02	0.06	-0.20	-0.07	-0.08	-0.21	-0.03	0.15	-0.02	1.00				
13	Tech: Biomedical/Ag	0.23	0.42	0.19	0.07	0.07	0.04	0.09	0.05	0.05	0.20	0.05	-0.10	-0.09	-0.37	1.00			
14	Tech: Communication	0.12	0.33	-0.05	0.06	-0.04	0.02	0.00	-0.06	0.11	-0.08	0.09	0.00	0.14	-0.24	-0.20	1.00		
15	Tech: Engineering	0.22	0.42	0.18	0.07	-0.09	-0.15	0.06	0.08	-0.07	0.10	-0.10	-0.01	0.10	-0.35	-0.29	-0.20	1.00	
16	Tech: Other	0.12	0.33	0.05	0.06	0.04	0.03	0.08	-0.02	0.03	-0.01	0.02	-0.08	-0.12	-0.24	-0.20	-0.14	-0.20	1.00

Table 2

Control Group:	MODEL 1 Controls DV= # SBIR	MODEL 2 FULL DV= # SBIR	Model 3 FULL DV= 0/1 SBIR
Licensed Technology	0.40*	0.45**	0.33**
	(0.21)	(0.21)	(0.16)
# Founders	-0.00	-0.06	-0.08
	(0.09)	(0.10)	(0.08)
Undergraduate	-1.55**	-1.28**	-0.45
	(0.61)	(0.61)	(0.60)
Age	0.06***	0.07***	0.02
	(0.01)	(0.01)	(0.01)
Tech: Software/EE	-1.65***	-1.67***	-1.15***
	(0.31)	(0.32)	(0.29)
Tech: Biomedical/Ag	0.10	-0.05	0.11
	(0.32)	(0.33)	(0.23)
Tech: Communication	-0.11	-0.27	-0.26
	(0.35)	(0.36)	(0.29)
Tech: Engineering	-0.22	-0.33	0.06
	(0.33)	(0.34)	(0.23)
University #1	-0.89***	-0.88***	-0.56**
	(0.33)	(0.34)	(0.26)
University #2	-1.11**	-1.01**	-0.71*
	(0.46)	(0.47)	(0.38)
University #3	0.69*	0.57	-0.07
	(0.38)	(0.38)	(0.28)
University #4	0.31	0.33	-0.09
	(0.33)	(0.33)	(0.24)
University #5	-0.38	-0.44	-0.18
	(0.32)	(0.32)	(0.24)
Serial Entrepreneur		0.28	0.07
(H1)		(0.29)	(0.21)
Knowledge Breadth		0.60**	0.48***
(H2)		(0.25)	(0.18)
Industry Experience		-1.00**	-0.09
(H3)		(0.48)	(0.38)
All-Expert Team		0.43**	0.12
(H4)		(0.21)	(0.16)
Mixed Team		0.77***	0.54***
(H4)		(0.28)	(0.21)
Constant_	0.05	-1.529	-0.97***
	(0.44)	(2.993)	(0.35)
Log Likelihood	-836.5	-825.9	-372.1
LnAlpha	1.14	1.07	-20.91
	(0.10)	(.10)	
Alpha	3.14	2.92	0.00
	(0.32)	(.30)	
LR Test of Alpha=0	G2=1117	G2=1101	
	(0.00)	(0.00)	
N Obs	561	561	561

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1