Essays on Entrepreneurship and Founder Pre-entry Knowledge

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Abstract

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This dissertation research extends our understanding of the ways in which founder pre-entry knowledge influences the evolution and performance of start-ups in technologically intensive industries. In the first chapter, I review existing literature and identify some open questions and theoretical and empirical puzzles. In the second chapter, using the minimally invasive surgical devices (MIS) industry as the context, I explore the implications of early choices of a new venture's knowledge structure, specifically its technological complexity, on the subsequent development of the venture's knowledge trajectory and its eventual performance through successful product commercialization. My findings deepen our understanding of the determinants of successful product introduction by start-ups and shed further light on the deep and lasting relationship between founders and the ventures they create. In the third chapter, I

focus specifically on VC-funded serial entrepreneurs across six high-tech industry contexts and investigate how knowledge gained through prior entrepreneurial experience can have a differential impact on different indicators of firm performance. Knowledge gained through prior entrepreneurial experience shapes entrepreneurs' behavior and perceptions in important ways and while extant literature has largely focused on the positive effect of this knowledge on a firm's likelihood of achieving success, this study identifies important trade-offs that arise due to the myopic nature of this learning. By focusing attention on two important types of founder pre-entry knowledge – technological knowledge and market knowledge and two indicators of firm performance – invention impact and economic success, this study uncovers important contingencies that shape the extent and nature by which prior experience translates into subsequent performance. Taken together, this dissertation research takes another step towards opening up the black-box of how founding teams impact firm performance.

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DEDICATION

To Thammi,

I miss you.

PREFACE

The founder of a new venture is known to have a lasting influence on the venture and its performance. However, despite its importance, much remains unknown about the ways in which the pre-founding experiences of the venture's founder impact the venture's subsequent performance. In particular, scholars have particularly emphasized the importance of further research for developing a better understanding of how an entrepreneur's past history, knowledge and experiences impact the organization (s)he subsequently founds (Sørensen & Fassiotto, 2011; Woolley & Fuchs, 2011).

In this dissertation, I investigate two important paths by which this relationship plays out in the context of new ventures through two empirical studies. In the first chapter, I conduct an extensive survey of the literature focused on how a founder's pre-entry experiences and knowledge impact new venture performance. In the second chapter, I explore the implications of the knowledge structure of founder for the subsequent development of the new venture's knowledge structure and its eventual performance. I also explore some key moderators that influence this important relationship. I draw on the literatures on imprinting, innovation and entrepreneurship to make my arguments. In the third chapter, I focus specifically on serial entrepreneurs and investigate how knowledge gained through prior entrepreneurial experience can have a differential impact on different indicators of firm performance. I theorize by combining insights from the literatures on learning, innovation and entrepreneurship. Taken together, this dissertation research underscores and further explicates ways by which founder pre-entry knowledge influences the evolution and performance of a start-up.

Table 1-1: Outline of the Essays

Essay	Research Question	Dependent Variable	Key Independent Variables
Essay 1	Survey of literature on founding teams	NA	NA
Essay 2	How does the extent of founders' technological complexity impact a new venture's ability to launch its first product?	(i) New Venture Knowledge Complexity (ii) Product introduction	(i) Founders' Knowledge Complexity (ii) Founders' Knowledge Breadth (iii) Organizational Knowledge Complexity (iv) Organizational Knowledge Breadth
Essay 3	How does heterogeneity in two key contexts – choice of technology and market, across successive ventures started by serial entrepreneurs, impact venture performance?	(i) Invention Impact of the later venture (ii) Economic Success of later venture	(i)Technology relatedness (ii)Market relatedness

CHAPTER 1 - THEORETICAL FOUNDATIONS AND LITERATURE REVIEW

"What's past is prologue."
William Shakespeare, *The Tempest*

INTRODUCTION

New ventures are often considered to be the drivers of innovation and economic development that periodically unleash the forces of 'creative destruction' (Schumpeter, 1934) and destroy and recreate the contours of market power. However, new ventures are also particularly likely to fail and suffer from the 'liability of newness' (Stinchcombe, 1965) as they lack the legitimacy and track record of more established organizations. Stinchcombe also argued that founding conditions have a disproportionate impact on the future of young start-ups. The structures and processes that are put in place early in the life of the venture typically become the foundation for all subsequent development within the venture. This claim has since accrued a great deal empirical evidence through the ensuing decades of research (for e.g., Beckman & Burton, 2008; Boeker, 1989; Burton & Beckman, 2007; Ding, 2011; Eesley, Hsu, & Roberts, 2014; Eisenhardt & Schoonhoven, 1990). In particular, the role of the founder (or founding team) has gained increasing prominence and importance in the study of entrepreneurial organizations.

Early research on entrepreneurial firms largely focused on the role of the solo founder in shaping firm outcomes but subsequently scholars have recognized that most entrepreneurial ventures are, in fact, team endeavors. For example, Wasserman (2012) found that over 84% of 10,000 companies he surveyed had more than one founder. Similarly, Beckman (2006) found

that over 90% of the high tech Silicon Valley start-ups sampled in her research were team endeavors. In fact, evidence suggests that start-up investors increasingly prefer to invest in teams and recently, the demand for co-founders has spurred a demand for online "matchmaking" services that pair co-founders by skill, personality and entrepreneurial pursuits (Alsever, 2014). Thus new venture teams are a typical and important aspect of entrepreneurship.

Extant research has established that many key new venture outcomes are significantly impacted by the knowledge the founding team brings to the venture and the dynamic among members of the top management team. Many different types of venture outcomes are known to be influenced including corporate strategy (Boeker, 1989; Romanelli, 1989), growth (Beckman, 2006; Colombo & Grilli, 2005; Eisenhardt & Schoonhoven, 1990), firm economic performance (Beckman, 2006; Carpenter, 2002; Cohen & Dean, 2005; Dencker & Gruber, 2014; Eesley et al., 2014; Roure & Keeley, 1990; Roure & Maidique, 1986), access to financing (Beckman & Burton, 2008; Chatterji, 2009; Hallen, 2008; Hsu, 2007), innovation (Arvanitis & Stucki, 2012; Koellinger, 2008) and product introductions (Beckman, 2006; Chatterji, 2009; Fern, Cardinal, & O'Neill, 2012). However, despite many significant advances in our knowledge of how founding teams impact new ventures, many gaps remain in our collective understanding of how differences in founding team compositions translate into differences in firm performance (Eesley et al., 2014). In particular, later in this review, I specifically discuss some open questions in this literature pertaining to the measurement of knowledge, the role of time, the role of context and the dynamics of status and power.

In the rest of this chapter, I will review the literature pertaining to the role of founder pre-entry knowledge on firm performance.

REVIEW OF RESEARCH ON NEW VENTURES AND FOUNDING TEAMS

Basis of Founding Team Formation

Firms founded by teams of entrepreneurs are much more likely to survive and to achieve faster growth than ventures started by individual entrepreneurs (Bird, 1989; Cooper & Bruno, 1977; Eisenhardt & Schoonhoven, 1990; Roberts, 1991). By 'founding team', I refer to the set of two or more individuals who jointly establish a business and who worked full time for the firm in executive level positions from the time of founding (Eisenhardt and Schoonhoven, 1990: p. 515). Prior research has shown that multimember teams enjoy several advantages over solo entrepreneurs such as (typically) a more diverse skill set (Vesper, 1990), greater capacity for innovation (Ruef, 2002) and higher levels of social and emotional support (Bird, 1989).

In order to understand why founding teams play such an important role in shaping new venture outcomes, it is helpful to review how founding teams are formed. Ruef and colleagues (2003) investigated five mechanisms that could undergird the formation of such teams using data from the Panel Study of Entrepreneurial Dynamics (PSED) to collect demographic and social network information on the founding teams of 816 business startups in the United States. Their results suggested that founding team structures are principally determined by homophily (particularly, ethnic and gender homophily) and network constraints imposed by strong ties. In their sample, about half the start-ups were solo endeavors, about a third consisted of people related by family ties and the rest were teams of unrelated individuals. Interestingly, the authors found little empirical support for composition based on functional diversification of achieved characteristics and differential homophily based on status expectations and instead observed patterns that suggested a preference for functional homophily within the teams in their sample. This suggests that founding teams of new ventures are often composed of individuals who share

similar demographic and functional characteristics compared to a benchmark of randomly assembled teams.

Table 1-2: Antecedents of founding team formation

Theory	General Claims
Homophily	Task groups tend to be composed of members with similar ascriptive characteristics (e.g., gender, ethnicity).
Functional	Task groups tend to be composed of members with diverse achieved characteristics (e.g., leadership, occupational competency).
Status Expectations	Individuals with high-status characteristics are more likely to attract other task-group members than are individuals with low-status characteristics
Network	The presence of prior network ties in a task group affects the extent to which the group exhibits diversity in ascribed and achieved characteristics
Ecological	Task groups tend to be composed of members in the same geographic locale and/or industry

excerpted from Ruef et al. (2003)

Why are founding teams important?

New ventures derive their early knowhow and capabilities from their founders. Founders vary in the extent of the knowledge they possess germane to the venture formation. Thus ventures are endowed with different stocks of knowledge and resources and thus come to develop different capabilities and knowledge search behavior contingent on these early proclivities. These behaviors have been shown to persist over time through the venture's subsequent development, even when the original management team is replaced, a phenomenon known as 'imprinting' (Stinchcombe, 1965). The literature on imprinting argues that ventures take on path dependence based on early decisions on team composition and organizational structure and process that ultimately determine its performance (Baron, Hannan, & Burton, 1999; Beckman & Burton, 2008; Boeker, 1989; Miles & Snow, 1978). The cause for this path dependence has been studied at multiple units of analysis – from individual level explanations of

bounded rationality to the development of firm-level capabilities, routines, and learning myopia (Nelson and Winter, 1982) that tend to transcend individuals and thus last long beyond the initial conditions that put them in place (Beckman, 2006; Beckman and Burton, 2008). In my review of the literature, I discuss two primary mechanisms by which founding teams impact venture outcomes: (A) by shaping the origins of firm knowledge and access to social capital; (B) by influencing the team dynamic based on founding team composition.

A. Origins of firm knowledge and access to resources

Huber (1991: p.91) stated, "what an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters (Huber 1991: p. 91)." Founders develop organized knowledge structures through their prior experience and knowledge which form the basis of templates of information and structure that they provide to emergent organizations (Walsh, 1995). A firm's knowledge structure is a template of organized knowledge that enables it to interpret and act in its environment (Fiske & Taylor, 1984; Walsh, 1995). Initially, the knowledge structure consists of a collection of discrete knowledge components. Experience helps to form linkages among the different knowledge components and create a more structured and integrated whole (Fern et al., 2012; Lurigio & Carroll, 1985). Since many decision-making scenarios pose multiple options and individuals are cognitively constrained (March & Simon, 1958), they tend to favor options that exploit their existing knowledge rather than explore new options. If founders develop a well-formed knowledge structure, they tend to repeat their learned behaviors when they start their own organization. This process can thus help to transfer and codify practices and knowledge across industries and organizations. Next, I

discuss the kind of experiences and knowhow that are most relevant and effective in helping new ventures to succeed.

(i) Prior work experience

Prior work experience often determines the opportunity set that founders are likely to consider and pursue (Shane, 2000). The mechanism by which this knowledge is useful for founders post founding follows three primary channels (Aldrich Howard & Ruef, 2006):

(a) Through job-specific contacts: Prior work experience can expose individuals to important business contacts who may subsequently become the basis of valuable network ties for the start-up in the form of suppliers, customers, employees or financiers. For example, Burton et al. (2002) found that founders of high tech ventures in Silicon Valley who were former employees of well-connected firms were more successful at raising outside capital than other entrepreneurs. Similarly, Baker, Miner and Ensley (2003) found that entrepreneurs tended to largely rely on their pre-existing networks as the means at hand for resource mobilization in the new venture. This network spanned both strong ties as well as weak ties i.e. close friends as well as acquaintances. In fact, as Baker et al. noted, "founders' networks provided information and resources even in the absence of any effort on the part of the founders to search for the deals around which they built their firms". Moreover, it was easier to seek and obtain help from industry 'experts' by leveraging pre-existing ties. Indeed, Aldrich et al. (1996) found that about three-quarters of 217 business owners in a Research Triangle Park study in 1992 had sought expert advice within the past year, with about 40 percent asking five experts or more for advice.

(b) Through organization or industry specific knowledge: Having prior work experience often enables founders to have easier access to valuable ideas and identify unmet business needs and opportunities. In addition, successful organizations develop routines and practices that "focus ever more narrowly and exclusively on a few cherished elements of strategy, on one category of activity" (Miller, Lant, Milliken, & Kom, 1996: p.864). Scholars have studied spinouts – organizations that are started by employees of existing organizations after leaving their former place of employment – and identified several important drivers that lead to their formation. For example, some high-tech organizations may expose employees to important technologies, business strategies as well as an entrepreneurial culture. This knowledge can facilitate the identification of new market opportunities outside of the 'parent firm' and can enable entrepreneurs to deploy their employee learning towards running their own start-ups (Klepper, 2001; Gompers et al., 2005; Agarwal et al., 2004). A prominent example of this phenomenon is Fairchild Semiconductors, which spawned ten new ventures in its first eight years, creating a lineage that ran across most of the thirty one semiconductor firms founded in Silicon Valley during the 60s (Saxenian, 1996). Examples of such 'Fairchildren' include Intel, LSI Logic and Advanced Microdevices.

Other organizations may expose employees to promising new technologies but may be unable or unwilling to exploit their full potential, thus forcing some frustrated employees to start their own ventures to pursue the unexploited market opportunities – a prominent example of this being Xerox Corporation (Klepper, 2001; Gompers, Lerner, and Scharfstein, 2005). In some cases, work experience can also provide individuals with transferable skills and information about entrepreneurial opportunities in closely related

industry contexts. For example, Van Maanen and Barley (1984) noted that ex-police officers often found detective and home security agencies.

In addition, prior experience in the same industry provides entrepreneurs with valuable knowhow pertaining to the competitive landscape, employment practices, customer preferences, industry specific norms and so on (Chandler & Jansen, 1992; Feeser & Willard, 1990). In case the founders have also held managerial roles within their prior employment, these experiences can enable them to develop a better ability to manage employees and other stakeholders (such as financiers, customers, suppliers etc.) and allocate scarce resources into productive use more effectively (Bates, 1990; Chandler & Jansen, 1992; Jovanovic, 1982; Kaghan, Strauss, Barley, Brannen, & Thomas, 1999). Gruber, Macmillan and Thompson (2012) found that found that prior entrepreneurial and management experience endowments enhance, while marketing and technological experience endowments constrain the number of market opportunities identified by the founders. They reasoned that domain specific expertise such as marketing and technological experience constrains cognitive flexibility while more general expertise such as entrepreneurial and management experience endowments enhances cognitive flexibility and consideration of alternative opportunities, thereby bolstering the construction of a firm's opportunity set. They also found that the number of market opportunities identified depends on the combinations of generalized and specialized endowments in the founding team. Teams composed of only specialists identify significantly fewer opportunities than those that combine specialists with generalists.

Prior research has also underscored the importance of prior functional experience of members of the top management team. In particular, firm performance outcomes were

found to be the highest in cases where the firm followed a competitive strategy that closely matched the functional experience of the founding team (McGee, Dowling, & Megginson, 1995; Shrader & Siegel, 2007). Similarly, Eesley, Hsu and Roberts (2014) found that founding teams that were mostly composed of individuals focused on the firm's technology performed best when the firm followed an innovation strategy. In sum, prior research has shown that prior work experience has a positive effect on many different forms of new venture performance.

The special case of *prior entrepreneurial experience*:

Prior entrepreneurial experience can endow founders with particularly valuable skills and knowledge that can help improve subsequent firm performance. Much of the knowledge associated with founding is tacit (Delmar and Shane, 2006) and thus prior founding experience can enable founders to better anticipate and plan for critical activities such as finding capital, hiring workers, choosing the appropriate market, establishing contacts with potential customers and developing new products (Brüderl et al., 1992; Aldrich and Ruef, 2006). Indeed, research has shown that experienced entrepreneurs are likely to have a richer and more refined cognitive representation of business opportunities than novice entrepreneurs (Baron and Ensley, 2006). This cognitive development confers benefits such as enabling serial entrepreneurs to recognize greater number of alternative business and market opportunities (McGrath and MacMillan, 2000; Gruber et al., 2008) and be better able to direct and allocate scarce resources (Baron and Ensley, 2006). In addition, experienced founders are more likely to have connections with key resource providers such as direct ties to venture capitalists which greatly improve their chance of obtaining timely access to venture financing (Hsu,

2007; Shane and Cable, 2002). In addition, such founders are likely to possess pre-existing network of ties (Rerup, 2005) that may render it easier to attract talent to the start-up. In fact, prior research has argued that even a failed prior venture provides significant learning advantages such as clearer causal linkages between actions and outcomes compared to success (McGrath, 1999). Prior failure can also protect against overconfidence and encourage greater pre-emptive action to deflect potential problems in the next venture (Rerup, 2005).

(ii) General human capital

New ventures are also directly impacted by the extent of general human capital possessed by their founders. Scholars have examined the educational qualifications of founders with particular interest in training in post-graduate education and their technical and business-related training to understand if this can help to explain heterogeneity in new venture performance. Scholars have also been interested in the prestige of the educational institution (Lester, Certo, Dalton, Dalton, & Cannella, 2006).

The following table provides a summary of some key papers investigating how founding teams' prior knowledge shapes the origins of new venture knowledge, access to social capital and eventually performance outcomes:

Table 1-3: Prior research on Founder Prior Knowledge Attributes

Study	Research Question	Founder Knowledge Attributes	Other key Independent Variable	Dependent Variable	Key findings
Agarwal et al. (2004)	How do the knowledge capabilities of industry incumbents affect the generation, development, and performance of "spin-outs"?	--	(1)Technological knowhow (2)Market pioneering knowhow	Spin-out generation	Incumbents with both strong technological and market pioneering know-how generate fewer spin-outs than firms with strength in only one of these areas.
Arora & Nandkumar (2011)	How does entrepreneurial opportunity cost impact start-up strategies and performance outcomes?	Opportunity cost = years of founder work experience; wages prior to starting firm in 2004 dollars; founder patents	Venture Quality = initial scale; parent trademarks; patents	Venture Success/failure (binary)	Entrepreneurs with high opportunity costs are not only more likely to cash out more quickly but are also more likely to fail faster.
Arvanitis & Stucki (2012)	How do founder characteristics influence the innovative activity of start-ups?	University Education; Technical education; industry experience; entrepreneurial experience; R&D experience	Motivation to innovate	Innovation	The combination of different founder characteristics such as university education (at best a combination of technical and commercial education), prior experience in R&D, and strong motivation to realize own innovative ideas increases the likelihood that a start-up has innovative activities, especially the likelihood of R&D activities, by 40%. Industry experience and prior entrepreneurship experience were found to have an insignificant effect.
Burton et al. (2002)	How do entrepreneur career histories shape the entrepreneurial process?	Prior founding experience; Prior management	Founder employer prominence	Adoption of Innovation strategy; Obtaining external financing at founding	(1) Entrepreneurs previously employed by prominent employers can more easily obtain external financing for risky ventures (2) Entrepreneurs with

		experience; Sales or finance experience			advanced degrees establish firms with innovation strategies, but entrepreneurs with sales or finance experience are less likely to pursue an innovation strategy (3) Entrepreneurs with senior management experience are more likely to obtain external financing.
Colombo & Grilli (2005)	What is the relation between the growth of new technology-based firms and the human capital of founders, with respect to the "wealth" and "capability" effects of human capital?	Education (Ed.) Business Ed. Technical Ed. Work Ex. Specific Work Ex. Technical Work Ex. Commercial Work Ex. Entrepreneurial Ex. Other Work Ex. Managerial Ex.	--	Number of employees of firms at survey date (logged)	Findings show that nature of the education and of the prior work experience of founders exerts a key influence on growth of venture.
Delmar & Shane (2006)	Does founding team experience enhance the performance of new ventures?	(1)Industry experience (2)Start-up experience		(1) survival (2) Sales per month	The results show that founding team experience enhances both new venture survival and sales, but that the effects are non-linear, and vary with venture age.
Fern et al. (2012)	How does founder experience constrain strategy choices during new venture formation, and how does variation in experience of the founder and the founding team break these constraints?	Knowledge recency; Knowledge variety; Shared knowledge; Unique knowledge;	Types of knowledge (Structural/Content)	(1) product market choice, (2) geographic market choice, and (3) resources choice	A founder's past experience strongly constrains choices, and the effect depends on the form of experience and type of strategy choice. Diversity of experience, at the level of the founder and founding team, lessens these constraints.
Geroski et al. (2010)	In what ways do founding conditions impact firm survival over time?	firm human capital	(1)industry entry rate (2)concentration	Exit (firm closure)	Large firms that have more human capital and those that are located in industries with low entry rates or high concentration are more likely to survive. The larger the initial stock of human

					capital in the firm, the lesser the (permanent) likelihood that the firm will exit
Gimeno et al. (1997)	What is the relationship between organizational survival, economic performance and the entrepreneur's own threshold of performance?	(1) formal education (2) Management ex. (3) Supervisory ex. (4) Entrepreneurial ex. (5) Specific human capital	(1)Intrinsic motivation (2)Parents owned a business	(1)Firm exit (2)Entrepreneur returns	Entrepreneurs with more general human capital perform better but do not necessarily survive more frequently. Firms are likely to survive based on thresholds determined by the entrepreneur's human capital characteristics, such as alternative employment opportunities, psychic income from entrepreneurship, and cost of switching to other occupations.
Gompers et al. (2005)	What are the determinants of entrepreneurial spawning from publicly traded corporations?	--	(1)firm patents (2)firm location	Entrepreneurial spawning from public corporations	Results suggest that the Fairchild-model (entrepreneurial learning) is a more important determinant of a firm's propensity to spawn a new venture capital start-up than the Xerox-model (employee dissatisfaction). Thus the breeding grounds for entrepreneurial firms are more likely to be other entrepreneurial firms.
Gruber et al. (2012)	How do founders' pre-entry knowledge and experience endowments shape an emerging firm's subjective market opportunity set (and consequently its strategic growth prospects)?	(1)Educational specialization diversity (2)Educational level diversity (3)Management experience (4)Marketing experience (5)Technological experience (6)Entrepreneurial experience	(1)Educational specialization diversity (2)Educational level diversity (3)Management ex. (4)Marketing ex. (5)Technological ex. (6)Entrepreneurial ex.	Number of market opportunities identified	Prior entrepreneurial and management experience endowments enhance, while marketing and technological experience endowments constrain, the number of market opportunities identified. In addition, the authors find that the number of market opportunities identified depends on the combinations of generalized and specialized endowments in the founding team.
Kor (2003)	How does management experience at firm, team	(1)Founder-Based Firm-	--	annual rate of sales growth	Founders' participation in the top management team contributes to the

	(group), and industry levels adds value to entrepreneurial growth?	Specific Ex. (2) Shared Team-Specific Management Ex. (3) Industry-Specific Management Ex.			firm's overall management team competence and results in a higher rate of sales growth. The logic proposed is that founders' historical and tacit knowledge of the firm's resources and capabilities strengthens the proper matching of firm resources and capabilities with opportunities.
McGee et al. (1995)	Should inexperienced managers cooperate simply to gain new knowledge and experience, or should they not cooperate unless they are experienced enough to know what they don't know?	(1)Management marketing ex. (2)Management R&D ex. (3) Management manufacturing ex.	(1)Management marketing ex. (2)Management R&D ex. management manufacturing experience	annual rate of sales growth	New high-technology ventures, whose management teams possessed more functional experience in the area most closely linked to their choice of competitive strategy, were more successful in their cooperative activities chosen to support that strategy.

B. Influence of team composition and team dynamic

Firm performance is also affected by the composition of the founding team and their relationship with each other. Founders may have a significant degree of pre-founding association or working relationship with each other or teams may consist of virtual strangers who may have come together based on a shared interest in a product or technology. Founding teams that have shared prior work experiences or company affiliations are more likely to have shared beliefs and a common frame of reference about work expectations and company culture (Baron et al., 1999; Chattopadhyay, Glick, Miller, & Huber, 1999). Such teams are likely to engage in local search and exploit existing routines that enable the newly founded venture to engage in "the exploitation of old certainties" (March, 1991: p.71). They are thus likely to exploit existing knowledge and competencies (Beckman, 2006). For example, Fern, Cardinal & O'Neill (2012) found that founding teams were more likely to select a particular product market, geographic market, or resource if its members shared common experience with that market or resource. Teams with shared prior experiences are also likely to demonstrate minimal disagreement on most issues and are likely to be strongly cohesive. Eisenhardt and Schoonhoven (1990) showed that founding teams with joint prior work experience make faster decisions – a capability which was particularly advantageous in high velocity environments – and start-ups founded by them demonstrate faster growth than other new ventures. However, having shared prior experiences also meant that founders spent less time brainstorming and creatively problem-solving. Beckman (2006) found that the best performing firms (with performance measured in terms of firm growth) were those that combined founding team members with shared as well as diverse prior company affiliations as such firms were more likely to be able to engage in both exploration as well as exploitation, thus attaining the performance benefits of ambidextrous organizations over time.

Founding teams may also vary in terms of the diversity by way of gender, age, educational background, functional experience etc. Indeed, diversity in teams has been recognized to be a central factor governing information processing and, eventually, performance of teams and organizations (e.g., Barsade, Ward, Turner, & Sonnenfeld, 2000; Carpenter, 2002; Carpenter, Geletkanycz, & Sanders, 2004; Hambrick & Mason, 1984; Jehn, 1995; Pelled, Eisenhardt, & Xin, 1999). Broadly defined, diversity is a relational concept that indicates recognition of differences among members of a team (Jackson, Joshi, & Erhardt, 2003) and has a long research tradition spanning over 50 years. Researchers have emphasized the importance of emergent knowledge and insights in teams that arise through the interactive restructuring of knowledge within groups (Levine, Resnick, & Higgins, 1993) that extends beyond the bounds of knowledge of individual members (e.g., Doise & Mugny, 1984; Perret-Clermont, Perret, & Bell, 1991). Organizations, especially in high tech industries, increasingly rely on a diverse workforce comprising of a diverse set of experts for developing innovative products, improving efficiencies within the organization and ultimately building a high performing successful organization (Cagan & Vogel, 2002; Dahlin, Weingart, & Hinds, 2005). This view that draws on ecological and cognitive models of variation, selection and retention (Campbell, 1960) suggests that diversity of attributes such as functional background, tenure and network ties can improve the knowledge and variety of ideas and solutions to problems available to a team thereby increasing its overall creativity, information processing abilities and thereby performance (Williams & O'Reilly, 1998).

However, unsurprisingly, working in diverse teams is also challenging. The very nature of diversity begets conflict and disagreement among team members who may be embedded in different structural or institutional bases. This line of reasoning draws on theories of similarity-

attraction (Byrne, 1971) and social categorization (Tajfel, 1981) that suggest that homogeneous teams tend to be the most cohesive as individuals are most harmonious when working with similar others. However, when team members are heterogeneous and representative of different attributes such as age, values and social categories, then hostilities and inter-group rivalries may arise, which can hamper performance (Williams & O'Reilly, 1998).

Extant research has also inquired into several aspects of the relationship between diversity of founders' prior experience and new venture performance. For example, Amason et al. (2006) found no direct relationship between the heterogeneity of the founding team's prior experience (in terms of education level, functional training and educational specialization) and firm performance measured in terms of sales growth, market performance, and profitability. Instead, their results showed that the novelty of the product or service moderated the effect of founding team heterogeneity on firm performance such that the relationship became more negative as the level of novelty increased. Boeker and Wiltbank (2005) showed that higher levels of functional diversity within top management teams of new ventures helped to provide ventures with a wider range of capabilities and led to lower levels of turnover within the team over time. Gruber, MacMillan and Thompson (2012) explored the relationship between educational heterogeneity (in terms of level and specialization) and experience endowments (in terms of management, marketing, technological and entrepreneurial experience) of the founding team and the identification of market opportunities for their newly founded ventures. Similarly, Foo, Sin, and Yiong (2006) found that educational diversity is positively associated with perceived team viability but not with member satisfaction. Drawing on similarity attraction theory, they suggested that this meant that team members do not derive the same sense of satisfaction from task achievement when members are diverse due to lower degree of interpersonal attraction.

Finally, Ucbasaran and colleagues (2003) demonstrated that heterogeneity in terms of a team's entrepreneurial experience was likely to lead to turnover within the management team. They argued that this is likely to be driven by power and status imbalances within the team with experienced team members attempting to dominate those who are inexperienced entrepreneurially, thereby reducing cohesion and creating conflict-induced team turnover.

Research has also underscored the importance of context, particularly environmental context as a key moderator of the relationship between team diversity and performance. For example, Hmieleski and Ensley (2007) showed that in dynamic industry environments, heterogeneous founding teams (defined in terms of diversity of functional background, education level, educational specialty, and managerial skill) achieve better performance when led by a directive leader, whereas in stable industry environments, heterogeneous founding teams achieved greater firm performance when led by an empowering leader.

However, despite its long and rich tradition of research, research on diversity of teams has yielded little consistent outcomes (for e.g., see reviews by Jackson et al., 2003; Van Knippenberg & Schippers, 2007; Williams & O'Reilly, 1998). While some studies report positive effects of diversity on performance with diverse teams outperforming more homogenous teams due to superior information processing, more innovative problem solving and better decision-making (Hoffman & Maier, 1961; Nemeth, 1986; Van Knippenberg, De Dreu, & Homan, 2004). In others, the results are reversed with more homogenous teams delivering superior results compared to diverse teams due to better communication patterns, lower conflict levels and increased team cohesion (Ancona & Caldwell, 1992; O'Reilly III, Caldwell, & Barnett, 1989; Pelled et al., 1999). Scholarly reviews summing up decades of empirical research on diversity have concluded that there are no consistent main effects of diversity on organizational

performance (Williams and O' Reilly, 1998) and that the direct effect of diversity on performance is essentially zero (Joshi & Roh, 2009).

Mirroring the larger trend in the literature, there is also no clear consensus on the relationship between founding team heterogeneity and firm performance (Klotz et al., 2014). Studies have produced contradictory results and comparability across studies is made difficult due to the popular use of heterogeneity indexes (such as a composite of age, educational level, functional work experience etc.) which often have little meaningful theoretical link connecting them, a practice that has been cautioned against. Instead, scholars have recommended the use of more narrowly defined constructs or the creation of theoretically relevant meaningful composites whose components were positively correlated with each other (Harrison & Sin, 2006).

In a further attempt to resolve the contradictions, scholars have suggested that the type of diversity may be the key driver of its impact on team performance. While informational diversity i.e. diversity in direct work-related attributes such as experience, educational background, functional training etc. is likely to improve performance, diversity arising from differences in 'visible' social categorizing or demographic attributes such as gender, race, age etc. are likely to have a deleterious effect on performance. However, results continue to be contradictory (for reviews, see Joshi and Roh, 2009; Van Knippenberg & Schippers, 2007; Jackson, Joshi, & Erhardt, 2003). These contradictory results have spurred greater interest in alternative conceptualizations of team compositions, particularly those that move away from the aggregation of atomistic individual characteristics to the group level.

The following table provides a summary of some key papers investigating how the diversity of the founding teams influences new venture outcomes:

Table 1-4: Prior research on founding team diversity

Study	Research Question	Diversity Attributes	Other key Independent Variable	Dependent Variable	Key findings
Amason et al. (2006)	How does the novelty of the venture impact the relationship between top management team heterogeneity and new venture performance??	Heterogeneity assessed on four dimensions: age (CoV), level of education (CoV), specialization of education (Blau), and functional background (Blau).	Novelty TMT size	(1) sales growth (2) profitability (3) stock market returns	The study finds that highly novel ventures with more homogeneous TMTs may perform better because more homogeneous teams will find high levels of behavioral integration easier to achieve.
Beckman & Burton (2008)	How does the breadth of founder prior experiences and early decisions about functional structures influence the types of executives who are attracted and retained and the types of structures that are subsequently put into place?	(1) Breadth of initial founding team's functional experiences (2) Depth of initial founding team's functional experiences	initial functional structures	(1) functional organizational structure(2) team member functional ex. (3) firm outcomes --> (a) time to funding (b) time to IPO	Founding teams strongly influence the TMT through path dependence. Consistent with homophily expectations, founding teams that begin with broadly experienced team members are more likely to attract broadly experienced executives. Consistent with ecological research, firms that begin with a range of functional structures are more likely to develop more complete functional structures.
Beckman (2006)	How do prior founding team affiliations shape firm behaviors (exploration versus exploitation strategy) and firm growth?	(1) Diverse prior company affiliation of founding team (count) (2) Common prior company affiliation of founding team	---	(1) Exploration and exploitation behavior (2) Firm growth in employees	Founding team prior company affiliations predict whether a firm pursues exploratory and exploitative behavior, and they also suggest that firms whose founding teams have both types of affiliations are more likely to grow over time. The mechanisms suggested for these linkages are the

					shared understandings that emerge from common prior company affiliations and the creativity associated with diverse prior company affiliations. Shared understanding suggests easier implementation and speed, whereas unique knowledge is associated with innovation and change.
Beckman et al. (2007)	How do TMT demographic characteristics affect firm outcomes for young high technology firms?	Functional diversity of founding team (Shannon index); Affiliation diversity (count); Affiliation overlap (HHI);	Turnover	(1) VC funding (2) IPO	The authors find that adding knowledge and experience (functional heterogeneity, prior management experience, affiliation diversity, and team entrances) help the firm obtain VC and go public.
Boeker & Wiltbank (2005)	How do firm growth, strategic change, and characteristics of the existing top management team influence the extent of top management team change in new ventures? (2) How are these changes affected by the power dynamics and oversight of the team, represented by different levels of ownership and board independence?	Top management industry experience; top management functional diversity (entropy)	Firm growth; Strategic Diversification; ownership (CEO/VC)	Top management change	TMT changes occur in cases of very low or very high firm growth, but are mitigated by a functionally diverse TMT. VC ownership and board representation increases change in TMT and managerial ownership decreases changes.
Eesley et al.	How does the	Diverse team	Commercialization	Favorable/Unfavorable	Founding teams that are diverse

(2014)	relationship between founding team composition and venture performance depend on the venture's strategy and business environment?	(count of functional roles); technically focused team;	Environment; Innovation Strategy	exit	are likely to achieve high performance in a competitive commercialization environment. On the other hand, technically focused founding teams are aligned with a cooperative commercialization environment and when the enterprise pursues an innovation strategy.
Eisenhardt & Schoonhoven (1990)	How do characteristics of the founding top-management team, strategy, and environment to the sales growth of newly founded ventures?	Team Strength: three conditions for strong teams: (1) at least three founders, (2) at least 50 percent joint experience, and (3) at least three years of industry experience variation); TMT Joint experience; TMT Heterogeneity of industry experience (standard dev.)	Market Stage; Competitive concentration; Technical innovation	Growth = difference in sales in each year of life through 1988 relative to sales at founding	The founding top-management team influences the growth of new firms. Specifically, the size of the team, members' past experience together, and members' heterogeneity in industry experience are linked with higher growth.
Foo et al. (2006)	How do team inputs and processes shape venture outcomes of team satisfaction and viability?	Educational background diversity (Teachman index)	(1)Presence of a distinct leader (2)Open communication (3) Social integration	Perceptions of team viability and member satisfaction	The presence of a distinct leader was positively related to team satisfaction, while member diversity in educational backgrounds was positively related to perceived team viability.
Hmieleski and Ensley (2007)	How does entrepreneur leadership, new venture top management team heterogeneity and industry environmental	TMT heterogeneity : summation (functional specialty(Blau), educational specialty(Blau), and educational level(Blau) ;	Leadership behavior; Environmental dynamism;	revenue growth and employment growth	In dynamic industry environments, startups with heterogeneous top management teams were found to perform best when led by directive leaders and those with homogenous top management teams performed best when led by empowering leaders. Conversely in

	dynamism relate to the performance of startups?	managerial skill (CoV))			stable industry environments, startups with heterogeneous top management teams were found to perform best when led by empowering leaders and those with homogenous top management teams performed best when led by directive leaders.
Ucbasaran et al. (2003)	What factors predict team member entry and exit in an entrepreneurial venture?	functional heterogeneity (Teachman index); entrepreneurial heterogeneity (Teachman index)	Team size; Team age (average);	Team member entry/exit;	Functional heterogeneity was weakly significantly positively associated with team member entry. Heterogeneity of prior entrepreneurial experience was significantly positively associated with team member exit.

DISCUSSION

The review of the literature on founding teams underscores the critical role they play in forging the foundation of the venture and their lasting influence on the growth potential that the new venture will exploit over time. Next, I focus more closely on the role of founder pre-entry knowledge, identify some outstanding theoretical and empirical puzzles and outline avenues for further research.

Measurement of knowledge

An important conclusion that can be drawn from the review of the literature on founder pre-founding knowledge is that there is little scholarly consensus on how different types of founder knowledge endowments impact venture performance (Delmar & Shane, 2006). This is a serious limitation for research on entrepreneurship (Dencker & Gruber, 2014). One possible reason for this shortcoming is that knowledge is an inherently challenging concept to measure. Most of the research in the literature has conceptualized knowledge using measures of formal education and work experience. However these measures ignore the role of innate capability or entrepreneurial talent that may be quite independent of years of formal education. Indeed, many successful entrepreneurs (including Steve Jobs, Richard Branson and Michael Dell) started their entrepreneurial careers with very limited formal education or resource endowments.

Some recent studies (e.g. Gompers et al., 2010; Eesley & Roberts, 2012) have attempted to address this issue by leveraging archival information on repeat entrepreneurs. However, this approach is only feasible for repeat entrepreneurs for whom longitudinal information on prior experiences and history can be collected. Another approach was adopted by Baron and Ensley (2006) who used content analysis of primary survey data using open-ended questions to deduce the cognitive prototypes of entrepreneurs. However, this approach too has its own limitations –

heavy reliance on primary data and the ability to measure only entrepreneur's intentions and priorities as opposed to capabilities. Thus while existing research has taken some steps towards accounting for this issue, the challenge of measuring knowledge helpful for bolstering success in entrepreneurship in a way that generalizes across both experienced and inexperienced entrepreneurs remains.

Role of time

The role of time in influencing the relationship between pre-entry knowledge and venture performance is a promising avenue of research that has received little research attention so far. While scholars have identified a wide variety of types of founder pre-founding knowledge that have implications for venture performance, we know little about the effectiveness with which they transfer to a start-up setting or the rates at which these different knowledge types depreciate or atrophy with the passage of time. Research on organizational learning has found considerable evidence that knowledge depreciates over time (Argote, Beckman, & Epple, 1990; Darr, Argote, & Epple, 1995; Thompson, 2007). Further, there is some evidence that knowledge from different types of experiences depreciates at different rates. For example, Madsen and Desai (2010) found in the context of the global orbital launch vehicle industry that knowledge from failure depreciates more slowly than knowledge from success. However, the entrepreneurship literature is noticeably lacking in studies examining the extent to which founders' knowledge depreciates over time. Hence this is an important direction for future research.

Another important challenge is attaining a deeper understanding of the role of pre-entry knowledge in changing the opportunity costs and ramifications for success or failure for entrepreneurs. A handful of studies (e.g. Arora & Nandkumar, 2011; Eberhart, Eesley, & Eisenhardt, 2014) have suggested that highly qualified entrepreneurs have a high opportunity

cost in undertaking entrepreneurship and hence may have a higher tolerance for failure than less elite entrepreneurs. For example, Arora and Nandkumar (2011) found evidence that entrepreneurs with high opportunity costs are likely to choose more aggressive strategies, undertaking greater amounts of risk to shorten the time to success but also embracing greater likelihood of failure, compared to those entrepreneurs with lower opportunity costs. However, an excessively high tolerance for risk may also be counterproductive for entrepreneurs and their investors. For example, Terralliance, a start-up founded by an ex-NASA scientist and successful serial entrepreneur, which attracted $296 million dollars in funding from elite investors including Kleiner Perkins and Goldman Sachs collapsed spectacularly under the weight of its own ambitions. An article in the business press narrating the story of its failure said, "All told, the investors had sunk nearly half-a-billion dollars into Terralliance, an astounding sum given the audacity of the company's aspirations — and the paucity of its accomplishments" (Lashinsky, 2010). Some scholars have attempted to analyze this paradox theoretically using cognitive lenses such as narcissism (Navis & Ozbek, 2016) and hubris (Hayward, Shepherd, & Griffin, 2006). For example, Navis and Ozbek (2016) theorize that entrepreneurs high in overconfidence and narcissism are propelled towards more novel venture contexts—where these qualities are most detrimental to venture success—and are repelled from more familiar venture contexts—where these qualities are least harmful and may even facilitate venture success. However, reconciling these cognitive concepts with the literature on founder pre-entry knowledge and addressing the paucity of studies examining these ideas empirically are significant gaps in the current literature.

There are many other unanswered questions related to the role of time in influencing knowledge and performance. For example, while extant literature has established the existence of imprinting in entrepreneurial settings, a deeper understanding of how entrepreneurs carry the

imprint of the past will be a valuable addition to the literature. It is unclear what determines the salience of a particular experience towards promoting entrepreneurial learning? What factors enable entrepreneurs to learn quickly and what factors detract from their learning? These are but some of the many interesting research avenues that can be probed pertaining to the influence of time in the relationship between founder pre-entry knowledge and firm performance.

Role of context

Another possible rationale for the mixed findings on the impact of founder pre-entry knowledge endowments on firm performance is that most studies examining this relationship have ignored the role of contextual relevance of the knowledge (Dencker & Gruber, 2014). As Argote and Miron-Spektor (2011) noted, "Experience interacts with the context to create knowledge." Thus an important challenge deserving of further research is unpacking the links between the type of founders' prior knowledge and its relevance to the venture's specific context. A handful of studies that have forayed in this direction suggest that this is a fruitful area of research. For example, Dencker and Gruber (2014) find that the value of founders' knowledge is relative to the type of opportunity exploited: high-risk opportunities favor founders with managerial experience, whereas low-risk opportunities favor founders with industry experience. Similarly Eesley et al. (2014) found that diverse founding teams are more likely to succeed in a competitive commercialization environment, while technically focused founding teams are aligned with a cooperative commercialization environment and when the enterprise pursues an innovation strategy. However many questions remain. For example, deep expertise or specialized knowledge can be helpful for achieving success, but so can diverse broad-based knowledge. When is one more important than the other? Founders who have previously succeeded may be less likely to explore new contexts (March, 1991). Under what conditions are successful

founders motivated to explore and innovate? How do diverse teams deal with failure? Pivoting to achieve product-market fit is a popular strategy among entrepreneurs and tech evangelists. What contextual team-level and firm-level factors enable firms to successfully pivot? Broadly, shedding light on the role of context in shaping the relationship between individual level actions and firm level outcomes is a ripe area for further research.

Dynamics of power and status

Research suggests that about 65% of start-ups fail due to conflicts among members of the founding team (Wasserman, 2012). As a Los Angeles-based venture capitalist, Mark Suster quips, "The fact of the matter is that co-founders spend most of their time fighting. But no one talks about it" (Alsever, 2014). Most empirical studies focusing on the diversity of new venture founding teams assume that all members of the founding team share equal status and power (e.g. Gruber et al., 2010; Amason et al., 2006). However, evidence from the popular press as well as scholarly literature on the entrepreneurial decision-making (e.g. Eisenhardt, 1989; West & Meyer, 1998) reveals that this is rarely true in practice. As the well-known start-up guru, Steve Blank quips, “Idealistic founders trying to run a venture with collective leadership, without a single person in charge, find that’s the fastest way to go out of business” (Blank, 2013). However, very little is known about the status and power dynamics within founding teams and more broadly among high-status individuals in nascent ventures. A handful of studies that have examined this issue show that this is a promising area of inquiry. For example, Boeker et al. (2014) show that while individually star inventors and technologically proficient founders (founder inventors) positively impact new venture performance, their joint presence on a new venture’s innovation team may limit product innovation, and suggest that conflicts arising between these high-status actors are likely responsible for this effect. Thus bringing greater

clarity to the impact of power and status dynamics in founding teams on firm performance will be an important contribution to the literature on management and entrepreneurship.

Conclusion

This chapter has reviewed key findings drawn from extant research on founder pre-entry knowledge and founding team composition and delineated what is known about their impact on a venture's evolution and performance. Although this literature has established the vital role played by the founders towards forging the nascent firm's resource base and deeply imprinting its development trajectory, yet important gaps remain in our understanding of how entrepreneurs carry forward their knowledge and learning from past experiences to their entrepreneurial endeavors. In the two empirical studies that follow, I endeavor to deepen our understanding of this important phenomenon by focusing on three key goals: (i) bridging the literature on innovation as it relates to knowledge search and the literature on entrepreneurship as it relates to founder pre-entry knowledge; (ii) providing greater clarity on the role of context in shaping the value and relevance of founders' knowledge endowments; and, (iii) deepening our understanding of the link between individual actions and organizational level outcomes

CHAPTER 2 - A KNOTTY INHERITANCE: INVESTIGATING IMPLICATIONS OF FOUNDERS' KNOWLEDGE COMPLEXITY ON NEW VENTURE PERFORMANCE

"Study the past if you would define the future."
Confucius

ABSTRACT

The launch of its first product provides a new venture with a route to earning revenue and market share which can enable it to forge the path to legitimacy and financial independence. Prior research suggests that in high tech settings, founders often launch start-ups to commercialize their own inventions and ideas. However, very little is understood about how the characteristics of the knowledge base of the venture's founders can impact the performance of a new venture. Drawing on a rich database of firms in the minimally invasive surgical devices (MIS) industry, I examine the influence of a founders' knowledge structure on the venture's performance. Specifically, I investigate how the extent of founders' knowledge complexity can imprint a venture's knowledge structure, and through this mechanism, impact the ability of the venture to successfully launch its first product. My findings deepen our understanding of the determinants of successful product introduction by start-ups and shed further light on the deep and lasting relationship between founders and the ventures they create. The findings from this study contribute to the literatures on innovation, imprinting and entrepreneurship.

INTRODUCTION

In his treatise on capitalist development, Schumpeter (1934) credited the entrepreneur with being the key agent driving innovation in products and processes in a capitalist society. Indeed, opportunity identification and exploitation have long been identified as the hallmark of an entrepreneur (Shane & Venkataraman, 2000). New entrants are known to contribute a disproportionately large share of new products and processes compared to incumbent firms who are active players in the product's market (Scherer & Ross, 1990). Thus the ability of new ventures to innovate and thrive is an important consideration for scholars of management and entrepreneurship.

Innovation can be conceptualized as a search process where knowledge is either created by making new combinations of technological components (Fleming & Sorenson, 2004; Nelson & Winter, 1982; Yayavaram & Ahuja, 2008), or by reconfiguring existing combinations (Henderson & Clark, 1990). Here, 'technological components' refers to "fundamental bits of knowledge or matter that inventors might use to build inventions" (Fleming & Sorenson, 2004: p.910). However, the ability of firms to assimilate the knowledge generated through this search process is a function of their preexisting knowledge structure (Cohen & Levinthal, 1990).

The concept of knowledge structure is central to the theory of information processing (Walsh, 1995). A firm's knowledge structure forms a template of organized knowledge that enables it to interpret and act in its environment (Fiske & Taylor, 1984; Walsh, 1995). Prior research has shown that a firm's knowledge base is composed of individual knowledge components that vary in the ways and extent to which they are related to each other (Ahuja & Morris Lampert, 2001; Fleming, 2001; Katila & Ahuja, 2002; Stuart & Podolny, 1996). The nature of these relationships has been shown to have important implications for a firm's

knowledge search trajectory and eventual performance (Yayavaram & Ahuja, 2008). The focus of this study is on the role of a specific structural characteristic, knowledge complexity, on influencing product introductions in new ventures.

Research on innovation has conceptualized invention as a recipe with ingredients comprising of both physical components and processes (Nelson & Winter, 1982). The details of the recipe guide inventors with specific instructions on how to combine the ingredients along with the proportion, order and contingencies governing the mixing so as to achieve an optimal result. Knowledge generated through such a recipe is considered complex if it consists of many interrelated ingredients such that a change made to any one ingredient causes ripple effects on the necessary changes in others.

Prior research has suggested that the transfer of complex knowledge is prone to many difficulties. Small errors in transmission of complex knowledge can significantly magnify in amplitude thus imposing large performance penalties (Rivkin, 2000). Due to the high level of interdependencies between components making up complex knowledge, transferring or making any improvements to technologies based on such knowledge requires a substantial coordination effort as a change in any ingredient would require a coordinated effort across multiple ingredients so as to preserve the desired outcome of the recipe (Rivkin & Siggelkow, 2003). Interdependence is a property of the natural world and hence needs to be uncovered through the process of exploration and discovery (Yayavaram and Ahuja, 2008). Thus the attainment of knowledge of such previously unknown relationships is a central aspect of technology search.

Prior research has suggested that exploiting complex knowledge within an existing firm can be problematic. Incumbent firms operate within the confines of an existing infrastructure and operating routines that rely on existing competencies and familiar search routines.

Assimilating complex knowledge is likely to necessitate changes across multiple 'ingredients' making up the firm's knowledge base, potentially impacting existing firm projects, thus rendering such a prospect unattractive, especially in the absence of complementarities across projects (Cassiman & Ueda, 2006). In addition, properties of complex knowledge such as its tacitness, uncertainty and sensitivity to small errors are likely to render it hard to understand and evaluate for resource-owners within existing firms. While prior research has argued that knowledge complexity may drive individuals to embrace entrepreneurship (Ganco, 2013), little is understood about how the extent and nature of knowledge complexity impacts venture performance as exemplified in the ability of the venture to launch its first product.

Although firms and particularly new ventures are known to create new knowledge via exploration of new knowledge domains, such exploration is likely to be within the confines of their existing technological and geographical positions (Stuart & Podolny, 1996). Search behavior is boundedly rational (March & Simon, 1958) and subject to the development of firm routines (Nelson & Winter, 1982). Firm search behavior is also likely to be 'imprinted' (Stinchcombe, 1965) by initial conditions, much of which is determined by the firm's founders (Hsu & Lim, 2013). Building on these insights, I posit that founders' knowledge characteristics are likely to have a lasting impact on the knowledge structure of the organization due to the combination of local search and strong interlocks between knowledge components.

In this study, I explore the implications of the knowledge structure of firm founders for the subsequent development of the new venture's knowledge structure and its eventual performance. I also explore some key moderators that influence the relationship between the venture's knowledge structure and subsequent performance outcomes. Though I raise the broad issue of how founders' knowledge structure impacts new venture performance, my specific

focus in this study is on one structural characteristic, complexity of knowledge. The specific research question I investigate is: *How does the extent of technological complexity of founders' knowledge impact a new venture's ability to launch its first product?* Drawing on literature on innovation, imprinting and entrepreneurship, I argue that founders' leave an imprint of their knowledge structure on the new venture and this imprint has significant implications for the venture's future performance outcomes.

THEORY AND HYPOTHESIS

For young technology companies, technological capabilities play a key role in determining the success of the venture (McGrath, 1995; Zahra & Bogner, 2000). Many firms derive this initial knowledge base through their founders (Eisenhardt & Schoonhoven, 1990; Gompers, Lerner, & Scharfstein, 2005). Prior research has shown that these stocks of knowledge and search routines that firms derive from their founders are not easily forgotten and firms are often 'imprinted' by these early experiences (Stinchcombe, 1965). Indeed, as Huber (1991: p.91) notes, "what an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters".

The literature on imprinting has argued that early choices in a firm's life can be an enduring influence on the venture's future strategy and structure, even outlasting the founder's departure from the venture. For example, Boeker (1989) found evidence that the prior functional experience of the founder determined the importance assigned to that function within an organization. Similarly, the initial strategic direction chosen by founders tends to persist over time (Boeker, 1989) which can have significant implications for eventual venture performance outcomes (Eesley et al., 2014). Beckman and Burton (2008) showed that firms that construct

narrow management structures at founding intending to build more complete structures later, often have difficulties later adding functional expertise not already embodied within the team.

Recently, Hsu and Lim (2013) have extended the findings from the literature on founder imprinting into the innovation literature by showing that initial 'knowledge brokering' (i.e. recombination with distant knowledge) by firms establish ongoing organizational innovation search trajectory. They showed that firms whose founders engaged in knowledge brokering at the birth of their venture continued to have long-term innovation trajectory advantages relative to initial non-brokers. In sum, a substantial literature has demonstrated that founders can leave a lasting impact on a firm's strategy and structure.

Next, I theorize how firm knowledge output and eventual performance outcomes may be imprinted by the structural attributes of its founders' knowledge, particularly focusing on the role of knowledge complexity.

Knowledge complexity and founder imprinting

Scholars of strategy have cited knowledge as *the* most strategically significant resource for a firm (Grant, 1996; Kogut & Zander, 1996; Spender, 1996). Knowledge resources have unique properties that enable them to create and sustain competitive advantage in endowed firms and individuals (King & Zeithaml, 2003). For example, unlike physical resources, knowledge does not deplete with use and can be used as many times as needed (Itami, 1987). Knowledge creates 'platforms' that enable firms to grow and expand into desired markets (Kim & Kogut, 1996). Indeed, as Ndofor and Levitas (2004) summarize, "Knowledge is valuable because it forms the bases for effective actions taken, inferior actions avoided, and promising actions that may be pursued in the future" (p.687).

In high tech industries, new organizations are often created to exploit unique knowledge possessed by their founders. In order to survive and grow, new ventures rely heavily on their

founders' knowledge and social endowments rather than proprietary knowhow or historical track records of success (Delmar & Shane, 2006). Although knowledge creation happens in the minds of individuals, organizations play a decisive role in articulating and amplifying this knowledge (Nonaka, 1994). Indeed, a primary driver for the conception of new ventures is the commercialization of new knowledge and technologies developed by their founders (Ganco, 2013; Gompers et al., 2005).

Prior research has suggested that the complexity of their technological knowhow may lead some inventors to embrace entrepreneurship to commercialize the inventions (Ganco, 2013). Simon (1962) defined complex knowledge as knowledge that possessed two key features: (i) the existence of numerous elements (ii) the elements are characterized by a high level of interdependence and rich history of interactions. Sorenson and colleagues (2006) adopt this definition and emphasize the extent of interdependence between the elements making up the knowledge. Characterizing a piece of knowledge as a recipe, they argue that diffusion of complex knowledge is particularly problematic as their reproduction is highly sensitive to small errors and discrepancies. Moreover, such knowledge can be particularly difficult for incumbent firms to imbibe and assimilate as they may be deterred by the tacit nature of the knowledge and the inherent uncertainty of realized outcomes. Indeed, the complexity of knowledge has long been recognized as a critical factor impeding rapid and efficient knowledge transfer (Hansen, 1999). Thus individuals possessing complex technological knowhow are likely to found new organizations in order to exploit the knowledge they possess.

Ganco (2013) identifies several advantages of founding new organizations for bearers of complex knowledge. First, developing products based on complex technologies are likely to benefit from a new supporting infrastructure and development team that is unencumbered by

previous history or established operating routines, requirements that are best met in a new venture. Second, developing products based on complex technologies are likely to require a focused effort without the distractions arising from multiple product lines or business units that are likely to be found in an incumbent firm. Third, as the leaders of the new organization, founders can design the organization in a way that is optimal for developing the product based on the focal complex technology. Fourth, securing financial resources to finance the technology is likely to be easier under the auspices of a new venture compared to an incumbent firm as resource providers are more likely to be focused on the merits of the new technology as opposed to looking for potential complementarities with an existing set of product and service offerings that may be hard to meet if the underlying technology is complex. In sum, entrepreneurs who invent complex technologies are more likely to found a new venture to exploit the technology compared to seeking to exploit the technology within an existing firm.

I contend that the extent of founders' knowledge complexity is likely to determine the extent of the new venture's knowledge complexity. Prior research on imprinting has suggested that prior history or experience with a norm or practice imprints individuals who in turn imprint their own organization as founders. For example, Phillips (2005) showed that founders of law firms that had previously worked for law firms where promoting female leadership was the norm were more likely to promote women into leadership positions within their own firm. Similarly Burton, Sorenson and Beckman (2002) found that founders who had previously worked for an entrepreneurially prominent firm were more likely to follow an innovation-based strategy compared to founders who did not have such a background. Ding (2011) showed that for-profit firms founded by founders holding a Ph.D. in the life sciences were more likely to adopt open science norms demonstrated by publishing in ISI-indexed journals suggesting that the founders'

education can imprint them with norms and beliefs that may transfer over to their choice of new venture strategies. This logic of 'imprint transfer' (Marquis & Tilcsik, 2013) suggests that founders of new ventures often carry over norms and practices from their prior experiences to the new venture.

The extent of the founders' knowledge complexity is likely to materially influence the structural complexity of the venture's knowledge. The reasoning for this can be intuitively understood by conceptualizing innovation search as a problem landscape as proposed by previous scholars (e.g., Fleming & Sorenson, 2001; Levinthal, 1997; Rivkin, 2000). This landscape is searched by inventors for promising inventions that are represented by peaks on the landscape. However inventors have limits to their capabilities as they are boundedly rational (Cyert & March, 1963) and have only limited understanding of the landscape. The ruggedness of the landscape is analogous to its complexity (Levinthal, 1997) with increasing ruggedness making the problem more difficult to solve (Rivkin, 2000). Thus founders that lay the foundation of a new venture's knowledge base with complex technological knowhow anchor the venture's search routines and search space within a rugged landscape. Since firms tend to search locally even when creating new knowledge, they are likely to be limited to the same set of interrelated ingredients in their ongoing knowledge search. Thus even in the absence of inertia, new ventures are likely to carry forward the same knowledge structure as endowed on them by their founders (Levinthal, 1997). Based on this logic, I argue that the extent of the complexity of a new venture's knowledge is likely to be a reflection of their founders' knowledge structure.

This leads me to my first hypothesis,

Hypothesis 1: *There is a positive relationship between the founders' knowledge complexity and new venture knowledge complexity.*

New Venture knowledge complexity and New Venture product introduction

For new ventures, bringing a product to market is the only way to survive and marks one of the central milestones in a venture's life. The introduction of its first product generates legitimacy for the venture and provides a route to earning revenue and market share that can enable it to evolve and grow (Schoonhoven, Eisenhardt, & Lyman, 1990). Successful product introduction enables a venture to establish itself and forge the path to financial independence. Thus the successful product introduction for a new venture is a key indicator of the venture's performance and likelihood of survival.

Products are artifacts combining components and technologies (Brusoni, Prencipe, & Pavitt, 2001). Components consist of distinct physical parts linked through a set of interfaces (Henderson & Clark, 1990), while technologies refer to the knowledge undergirding the product design and manufacturing (Pavitt, 1998). The process of designing a product often involves multiple iterations as feedback from potential users is received or development problems are encountered during production. These iterations may require changes or adaptations to be made to the underlying knowledge. If the underlying technology is complex, change in any ingredient can have ripple effect on multiple other ingredients making up the recipe. Knowledge that is complex is characterized by a high degree of interdependence so that a change in even a single ingredient can dramatically reduce the usefulness of the recipe. Sorenson and colleagues (2006) note that for knowledge characterized by high complexity, "[i]ngredients depend on one another in an extremely delicate way and none produces much benefit unless all align perfectly" (p.999). On the other hand, knowledge that is simple is characterized by low interdependence between the ingredients thereby making it significantly easier to adapt and change ingredients independently. Thus the more complex the underlying technology upon which the product is

based, the greater the number of potential problems the firm is likely to be required to solve in order to successfully commercialize its product.

In addition, product development may require knowledge of the underlying technology to be disseminated among members of the development team within the focal firm. This would require the articulation of tacit cues that would make the knowledge available to others in an understandable way in order to be replicated or advanced. However, at higher levels of complexity, knowledge transfer is challenging even within the social circles where the knowledge originated (Sorenson et al., 2006), thereby raising challenges in communicating knowhow within the members of the development team. As Rivkin (2001) notes, "[Knowledge that is] complex poses a challenge to both voluntary and involuntary transfer"(p.279).

The above discussion suggests that higher levels of complexity may make it hard for new ventures to commercialize the innovation. Accordingly, I posit that the higher the complexity of new venture knowledge, the lower the likelihood of successful product introduction for the focal venture. This leads to my second hypothesis,

Hypothesis 2: *There is a negative relationship between the complexity of new venture knowledge and the likelihood of first product introduction.*

Technological breadth and New Venture product introduction

Technological breadth is well recognized as a key ingredient of successful innovation generation (Dahlander, O'Mahony, & Gann, 2016; Jeppesen & Lakhani, 2010; Leiponen & Helfat, 2010). I argue that for a new venture, two kinds of technological breadth are of particular importance- the pre-founding technological breadth of the venture's founders and the technological breadth of the venture itself. I discuss these two types of breadth and their implications for a venture's performance next.

New ventures derive their early knowhow and capabilities from their founders. Founders develop organized knowledge structures through their prior experience and knowledge which form the basis of templates of information and structure that they provide to emergent organizations (Walsh, 1995). An important attribute of founders' knowledge pertains to the breadth of their technological capabilities at the time of founding the firm. Different classes of technologies represent different technological possibilities. The effect of the pre-founding technological breadth of a venture's founders on firm performance involves interesting contradictions. First, greater technological breadth can provide a founder with access and exposure to a broad range of technologies that may enable the founder to 'select' the technology that is most viable and has the greatest potential for successful commercialization (Dosi, 1982; Quintana-García & Benavides-Velasco, 2008). Second, having high knowledge breadth enables individuals to broker knowledge across multiple scientific areas of experience to resolve technological problems (Hargadon & Sutton, 1997), an important advantage for resource-constrained start-ups.

However, a high level of founders' knowledge breadth also confers some important disadvantages to ventures. Broad technological breadth has an opportunity cost in terms of the attention available to develop expertise or specialization in a particular technology or set of technologies (Dahlander et al., 2016; Ocasio, 1997). As noted by Dahlander and colleagues (2016), "Individuals live within the same 24-hour day and cannot, like a firm, hedge against the risk embedded in many different search strategies to achieve innovative results" (p.261).

Second, founders with narrower technological breadth are less likely to suffer from the risk of 'negative transfer' (Ghosh, Martin, Pennings, & Wezel, 2013), thereby potentially improving the utility of the knowledge they bring to the firm and reducing the risk of their taking

speculative technological bets. 'Negative transfer' (Bartlett, 1958) in the psychology literature is said to occur when prior experience interferes with learning in a new context, with detrimental impact on performance. For example, Besnard and Cacitti (2005) demonstrate how factory accidents can result when factory operators, because of their prior experience, erroneously perceive a new device to be familiar. I suggest that a narrow but specialized knowledge base is likely to enable founders to have a comprehensive and up-to-date understanding of the technology they develop in their new venture, which in turn is likely to improve the reliability of their knowledge and improve their ability to translate it into a product (Martin & Mitchell, 1998).

Although founders' knowledge breadth impacts firm performance in both positive and negative ways, I expect the negative effect of founders' knowledge breadth to dominate and have an overall negative influence on the ability of the firm to successfully launch its first product. This leads to the following hypothesis,

Hypothesis 3a: *There is a negative relationship between founders' knowledge breadth and the likelihood of first product introduction.*

In addition to the influence of the founders' pre-founding technological breadth, the venture's technological breadth based on its past history of technological development is also likely to be an important predictor of the venture's ability to successfully launch products. A firm's patents represent imperfectly related individual projects – even if they share common technological components or goals (Ghosh et al., 2014). Since firms are less encumbered by limitations to processing and managing information than individuals, there are some clear initial advantages to higher technological breadth. First, prior research suggests that greater breadth enables a firm to improve its ability to solve problems by enriching its understanding of potential variations in recombinatorial search (March, 1991; Fleming & Sorenson, 2001). This superior

technological knowhow is likely to translate into better new product development decisions (Ding & Eliashberg, 2002; Laursen & Salter, 2006; Leiponen & Helfat, 2010). Second, firms with greater technological breadth can hedge the risks involved in product development by cultivating a portfolio of search initiatives with different risk profiles (Dahlander et al., 2016).

However, increasing venture technological breadth comes at a cost. First, greater technological breadth increases the challenge of managing and integrating the new knowledge (Grant, 1996). Technologically, greater breadth might require a firm to invest increasing time and resources towards establishing common interfaces among knowledge elements (Katila & Ahuja, 2002). Managerially, this may to require a firm to allocate greater managerial attention to the task of managing this increasing knowledge base at the expense of commercialization-focused activities. As noted by Ocasio (1997: p.203), for a firm to succeed, decision-makers need to "concentrate their energy, effort and mindfulness on a limited number of issues". A venture's ability to attain this balance may be compromised with increasing levels of technological breadth. Second, increasing breadth might lead the firm to have an abundance of ideas, which can make it hard for it to stay strategically focused and may distract it from the actual task of translating one idea to a commercialized product (Koput, 1997). Thus, although technological breadth provides important initial performance benefits to start-ups, the concomitant costs are likely to eventually overcome the benefits.

Based on this logic, I posit that the initial positive influence of venture technological breadth on the new venture's ability to successfully launch its first product will be tempered by the concomitant costs associated with higher levels of technological breadth. In other words, beyond a point, the costs associated with high venture technological breadth would outweigh the

benefits, leading to a lower likelihood of successfully introducing the firm's first product. This leads to the following hypothesis,

Hypothesis 3b: *There is a curvilinear (inverted-U shaped) relationship between the new venture's knowledge breadth and the likelihood of first product introduction.*

The moderating role of technological breadth

Scholars of innovation have emphasized that having knowledge about a diverse range of technologies is critical for successful innovation (e.g., Dosi, 1982; Nelson & Winter, 1982). Although knowledge of diverse technologies can be helpful for innovation as argued broadly, I contend that such knowledge may be counterproductive when dealing with complex technologies where the incisive insights arising from narrow but focused knowledge is more likely to be valuable. Thus I argue here that new ventures whose founders possess complex but focused technological knowhow are particularly likely to benefit from significant performance advantages.

Complex technologies comprise of many interdependent components. These interdependencies reflect the degree to which two corresponding elements are related in the natural world. This knowledge of interdependencies between components is discovered during the process of technology search and innovation and make up very valuable knowledge for inventors and firms (Yayavaram and Ahuja, 2008). Such discoveries are likely to be facilitated by the knowledge of what assumptions underlie existing sources of value and the ability to identify "what rules to break" (Taylor & Greve, 2006: p.726), insights that typically arise from deep understanding of a domain. As Maggitti et al. (2013) noted in their in-depth examination of individual inventors' search processes, inventors obtained greater perspective of relationships

within an information landscape by "zooming in", a practice that required effort and persistence as it could be tedious and time-consuming.

The transformation of complex technologies into a product can be challenging as highly complex technologies may have emergent properties that cannot be predicted from first principles thus significantly increasing the potential for design problems during product development (Nightingale, 2000). As noted by Cohen and Levinthal (1990), the ultimate success of a firm's ability to innovate and problem-solve lies "on the individuals who stand at the interface of …the firm and the external environment" (p.132). Thus new ventures that have complex knowledge structures are particularly likely to benefit from the presence of founders who have the ability to resolve technological problems.

However, individuals have limited attention and ability to manage disparate domains of expertise (Dahlander et al., 2016). Prior research argues that inventor specialization becomes necessary as the "burden of knowledge" increases over time (Conti, Gambardella, & Mariani, 2013). Successful problem solving involves "discipline, information comprehensiveness, and acquisition of up-to-date knowledge as ongoing", (Maggitti et al., 2013: p.94) – an already challenging task that is likely to be further compounded in the presence of technological complexity. Hence, I contend that in dynamic environments such as one characterized by new venture settings, founders with relatively narrow, as opposed to broad, technological knowledge are likely to be significantly more effective in mitigating problems that arise during the commercialization of complex technologies. Hence I suggest that the presence of founders with low technological knowledge breadth is likely to moderate the relationship between new venture complexity and venture performance. Thus I posit,

Hypothesis 4a: *The relationship between the complexity of new venture knowledge and new venture product introduction is moderated by founders' knowledge breadth such that low technological breadth mitigates the negative influence of high levels of complexity on the likelihood of first product introduction.*

The transformation of complex technologies into a product can be challenging as complex technologies may have emergent properties that cannot be predicted from first principles (Nightingale, 2000). In contrast to simple technologies, complex technologies typically involve a pyramid of problem solving tasks that mirror the physical structure of the product (Walker, Graham, & Harbor, 1988). Having a broad and diversified knowledge breadth confers some important advantages to firm that deal with a complex knowledge repository. First, a broad technological breadth enables firms to broker knowledge across multiple scientific areas of experience to resolve technological problems (Hargadon & Sutton, 1997). This allows firms to enrich the pool of solutions available to resolve unpredictable technological challenges (Leiponen & Helfat, 2010), a key advantage when working with complex technologies. Second, working with complex technologies is likely to involve a higher level of risk in decision-making error, due to the high level of inter-relatedness between the components and the concomitant possibility of erroneous combinations and redesign feedback loops where a single component change creates the necessity of changing multiple related components (Nightingale, 2000).

Thus building on research that shows that breadth improves firm performance by enabling firms to spread the risk of their innovative endeavors (Klingebiel & Rammer, 2014), I posit that a broader technological knowledge base may allow ventures working with complex knowledge to improve their performance. In sum, I contend that a broad technological breadth is particularly likely to benefit firms dealing with complex technologies and enable them to

successfully introduce new products. Thus I propose that the technological breadth of the firm moderates the relationship between complexity and new venture product introduction so that at higher levels of complexity, new ventures with higher technological breadth are like to enjoy significant performance advantages over new ventures with lower technological breadth. This leads to my next hypothesis,

Hypothesis 4b: *The relationship between the complexity of new venture knowledge and new venture product introduction is moderated by the venture knowledge breadth such that high breadth mitigates the negative influence of high levels of complexity on the likelihood of first product introduction.*

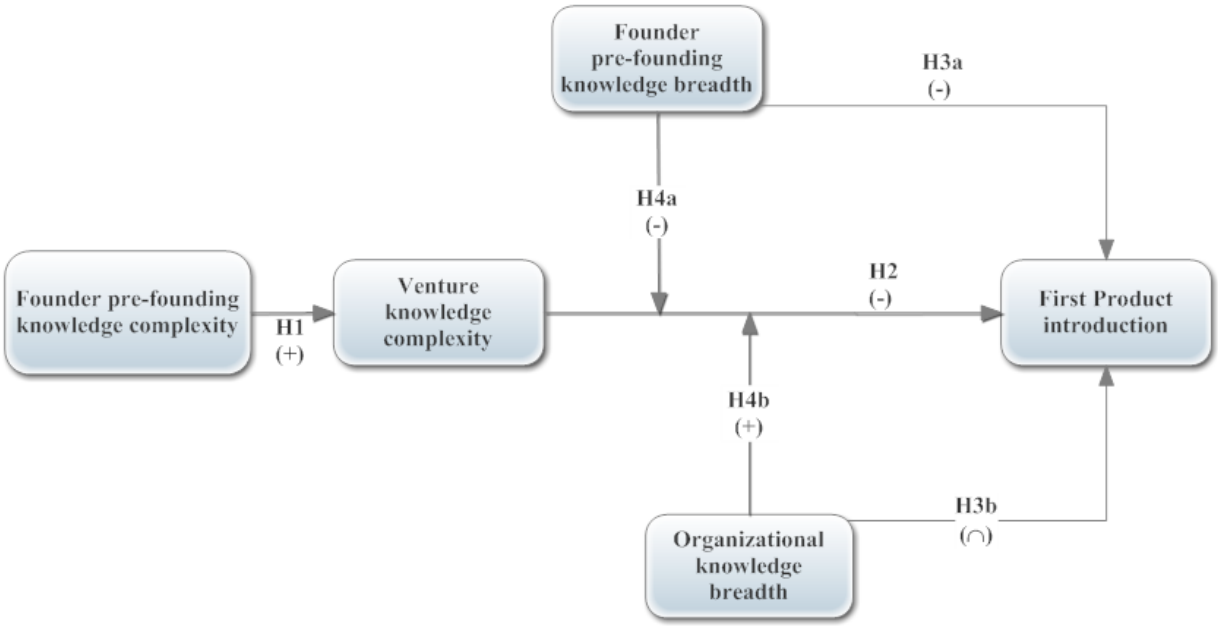

Figure 2-1: Conceptual Model

METHODS

To test my propositions, I use data on the segment of the medical device industry that develops devices for use in minimally invasive surgery (MIS). These devices reduce patient trauma, healing times, and infection rates. MIS devices are technologically complex and encompass multiple underlying patents. The protection of intellectual property via patenting is a vital part of the product development cycle in this industry and innovation and collaboration can be observed through the patenting record (Cohen, Nelson, & Walsh, 2000; Graham, Merges, Samuelson, & Sichelman, 2009).

I begin with data on the entire population of hand-collected U.S. based firms in the MIS industry. Portions of this data have previously been used in forthcoming studies (Pahnke, Katila, & Eisenhardt, 2015a; Pahnke, McDonald, Wang, & Hallen, 2015b). Although the data spans the entire population of U.S. based firms in the industry, I restrict my analysis to firms that filed a patent, attempted to develop an MIS device (not manufacturers or distributors), that were independently founded (i.e., not spinoffs) between 1986 and 2007, and for which data on founding teams was available.

I start the sample in 1986, which is when industry informants and medical industry experts indicate the first firms were founded to develop MIS devices. I excluded firms for which complete founder data was not available and this limited the sample to 172 firms. I matched this data with information on patents associated with the new venture. I also created a comprehensive dataset of all patents that were filed and subsequently granted by firms in the dataset. To create this dataset, data on patents and inventors was triangulated across both the Delphion and disambiguated inventor data obtained from Harvard Dataverse (Li et al., 2014). For every inventor associated with these patents, I created complete inventor histories that enabled me to track their collaboration histories longitudinally, building on previous studies which utilized

patents to measure inventor team characteristics (Fleming, Mingo, & Chen, 2007; Paruchuri, 2010; Phelps, 2010; Singh & Fleming, 2010). Data on patents extends from 1976 –2010 providing an adequate period of time in which to observe subsequent patenting activity of the new ventures. Since most of the variables of interest rely on patent data, I limit the sample to firms that have at least one patent in the first five years following the founding date. This process led the final sample size for this study to be limited to 132 firms.

A particularly important consideration in this study is the ability to accurately identify firm founders' patenting activity prior to the founding of the venture among all inventors recorded in the US patent database, so as to ascertain the influence of the founders' knowledge on the patenting activity of the venture. I disambiguate firm founders by programmatically checking whether the founder's name or a linguistically close version of the same (calculated by an algorithm called the Levenstein's distance) is also listed as an inventor of a patent associated with one of the firms the founder is known to have worked for. If yes, then I assume that the disambiguation problem has been resolved and consider the data to be matched.

For example, Randy Werneth, one of the founders in the dataset founded a company called Ablation Frontiers. Randy did not engage in any patenting activity at the start-up and so there is no direct way to associate Randy's prior patenting activity with the start-up he founded. However, based on additional hand-collected data on founder backgrounds, I know that Randy's prior employers included "Medtronic; Micro Therapeutics; Innercool therapies and Edwards Lifesciences; Heart Rythm Society". Using this information, the algorithm can identify whether a person called Randy Werneth is listed as an inventor for a patent assigned to "Medtronic", "Micro Therapeutics", "Innercool therapies", "Edwards Lifesciences", "Heart Rythm Society". In this case, a "Randy Werneth" is found who had patented for "Vascular Control Systems, Inc.",

but whose patenting record does not reflect any of the prior employers of the founder of Ablation Frontiers. I then test to see whether a person with last name Werneth is listed as an inventor for a patent assigned to "Medtronic", "Micro Therapeutics", "Innercool therapies", "Edwards Lifesciences", "Heart Rythm Society". This yields records for "Randell L. Werneth", an inventor whose prior inventor history includes patents for Medtronics as well as Innercool Therapies. This inventor's patenting history is then matched to the founder of Ablation Frontiers, Randy Werneth. Thus by using this approach, in this example, I was successfully able to prevent a false positive match and was able to disambiguate and identify the correctly matched inventor data with the founder data.

Measures

Dependent variable

Product Introduction: MIS devices cannot be sold in the US without first receiving FDA approval (Chatterji, 2009). The date of an FDA approval is a good proxy that indicates when a product was released to the market. Moreover, interviews with industry experts indicate that FDA approval is the most important predictor of commercial success. The dependent variable, likelihood of *product introductions*, is measured as a binary variable that is set to 1 when a firm first successfully receives class III device approval from the U.S. Food and Drug Administration each year. Data on all product approvals was gathered from the FDA's medical device databases. The measure for the dependent variable on product introductions included both 510k and PMA approvals, two separate forms of FDA device clearance. The 510k approval process involves relatively incremental advances in technology and clinical applications, which allows for more a more streamlined FDA review. In contrast, the PMA approval process is geared toward more novel innovations, requiring a more elaborate process of review.

Independent Variables

Technological Complexity: I measure technological complexity by following the approach taken by Ganco (2013) and utilizing a single industry measure of technological complexity. This measure is based on the NK paradigm (Kauffman, 1993). Here N refers to the number of components and K refers to the number of interdependencies per component. While analogous to measures used in previous studies that have measured complexity (e.g., Fleming & Sorenson, 2001, 2004; Sorenson, Rivkin, & Fleming, 2006), this measure of complexity is a single-industry measure unlike the cross-industry measure used in most previous studies. The measurement of *K* is calculated as follows:

$$Interdependence\ of\ subclass\ i\ \equiv {K_i}^n = \sum_{j \in l_{-i}}^{n} \frac{count\ of\ patents\ in\ subclass\ i\ and\ j}{count\ of\ patents\ in\ subclass\ i}$$

Where, *j* belongs to all subclasses except *i*. The measure *K* for patent *l* is calculated as:

$$Interdependence\ of\ patent\ l\ \equiv {K_l}^n = \frac{1}{count\ of\ subclass\ of\ patent\ l} \sum_{i \in l}^{n} K_i$$

N is operationalized as the count of patent subclasses and the final complexity measure is computed as *K/N*. To calculate the knowledge complexity of a firm in a given year, I took the maximum complexity value across all patents awarded to the firm in a given year.

To calculate the pre-founding knowledge complexity for the founders of a firm, I calculated the complexity of all patents successfully granted to an individual founder of the firm in the five-year period prior to the founding of the firm. I then identified the maximum complexity value in a given year for a focal founder inventor. I then took the average of the maximum complexity of the patents filed by the founder for each year over the five year period

prior to the founding of the start-up. If the firm had multiple founders who engaged in patenting, I followed this approach for each founder and calculated the average across all the founders.

Technological Breadth: I measure technological breadth using an entropy index of diversification that utilizes information on the classification of patents into patent classes by the USPTO. The formula for this index is:

$$\sum_{1}^{N} f_i * \ln(\frac{1}{f_i})$$

where, *N* represents the total number of classes where a focal firm has patents, based on the cumulative history of patenting of the firm since founding and f_i represents the fraction of the firm's patents in the *i*th patent class. The value of this index increases as firm breadth increases. A similar measure for measuring technological breadth was used by Mindruta (2013).

Control Variables

I included a number of control variables in the analyses. New venture innovation outcomes are likely to be affected by the amount of resources at the disposal of the new venture (Kortum & Lerner, 2000). Utilizing data on firm financing obtained from VentureXpert, VentureSource, and the government's SBIR program, I controlled for the total amount of financing received by a firm. The net total was captured in the variable *total funding*. This allowed me to control for performance differences due to heterogeneity in financial resources. The variable was lagged by one year in order to account for response time for the funding to impact performance and transformed to account for skewness in its distribution using the logarithm of the original value. The age of the firm can represent heterogeneity in the extent of legitimacy earned by a venture. This was captured in the variable *firm age*. As more prominent venture capital firms might plausibly provide superior contacts, expertise, and resources to their target firms (Stuart, Hoang, & Hybels, 1999), I also controlled for heterogeneity of resource providers by tracking whether or

not the firm had a high status venture capital investor, coded as the variable, *VC status*. This binary variable is set to 1 if the firm received investment from one or more of the top 30 VC organizations in terms of their eigenvector centrality within the VC co-investment networks in technology industries (Bonacich, 1987; Katila, Rosenberger, & Eisenhardt, 2008). Differences in regional ecosystems could impact the firm's ability to innovate. Hence I control for geographical factors related to firm location by including binary variables if the firm was located in the *Bay Area, Orange County, Boston or Minneapolis* — four regions noted for medical device innovation. Access to strategic partnerships can also shape performance differences among startups (Baum, Calabrese, & Silverman, 2000). To account for this, I include a binary variable that is set to 1 if a firm participates in an alliance with another firm. To control for heterogeneity arising from differences in founding team size, I control for the size of the founding team (*number of founders*). I also controlled for the number of active inventors in a firm (*team size*) as larger teams have both broader and deeper knowledge from which to draw. I did this by including a count (two-year moving average) of inventors who are active in patenting for the new venture.

Empirical Strategy

My analysis employed several empirical techniques. To test my first hypothesis examining the relationship between founder pre-founding knowledge complexity and venture knowledge complexity, I used Ordinary Least Squares (OLS) regression with fixed effects for firm and year. For testing the rest of the hypotheses, I used the semiparametric Cox proportional hazards model (Cox, 1972), a common choice for studying time-to-event data. An important advantage of the Cox proportional hazards method is that it does not make strong assumptions about the baseline hazards function. Prior research shows that incorrect parametric assumptions

may lead to biased estimates of how the covariates impact the hazard rate (Blossfeld & Rohwer, 1995). The formal model can be represented as:

$$h_i(t) = h_0(t)\, exp(\beta_i' X_i(t))$$

where, $h_i(t)$ is the hazard of the first product introduction by firm i at time t, $h_0(t)$ is the baseline hazard function that is left unspecified, β' is the vector of coefficients to be estimated and $X(t)$ is the vector of covariates. The model is estimated by finding estimates of the coefficient vector that maximizes the partial likelihood of observing the data.

To analyze the data, I organized it into yearly spells, starting with the founding year of a firm. I then followed the firm every year until the firm launched its first product or one of two things happened: the firm ceased to be a start-up due to an exit or I reached the end of my observation period, the year 2007. All time varying covariates were updated yearly and each yearly spell that did not yield a product launch was treated as right censored. To fulfill the assumption of proportional hazards for time-dependent covariates, an interaction with time was included for these covariates. I used the *stcox* routine for analyzing survival time data available in Stata 14 and adjusted the standard errors for non-independence across multiple spells observing the same firm.

I also ran an alternate event history model specification to account for the competing nature of the two outcomes that many firms in my dataset encountered: a product launch or firm exit (typically due to firm failure or an acquisition). Since these two outcomes are mutually exclusive events for a specific firm in my data, a competing hazards model (Allison, 1984) offers the advantage of accounting for this aspect of my data. Unlike the Cox model, where censoring only indicates the non-occurrence of an event of interest, the competing risks model prevents the simultaneous occurrence of the competing events: product launch and firm exit. I implemented

this method using the *stcrreg* routine in Stata 14. This function uses an event-specific cumulative incidence function (Fine & Gray, 1999) that represents the probability that a focal firm will experience the primary event of interest (first product launch) instead of focusing exclusively on cause-specific hazards. This technique allows me to account for the probability of the alternative event (bankruptcy or acquisition) that can also cause the firm to leave the observation window besides the primary event of interest.

RESULTS

Table 2-1 presents the descriptive statistics and correlation matrix for the full sample of firms in the dataset. The results from the OLS regression testing Hypothesis 1 predicting the likelihood of venture knowledge complexity is shown in Table 2-2. Model 1 presents the results with only the control variables included and Model 2 adds the main effect variable, founders' knowledge complexity. As hypothesized, the coefficient is positive and strongly significant (β = 0.227, p <.001), providing evidence that the extent of founders' knowledge complexity strongly influences the extent of venture knowledge complexity.

Table 2-3 presents the results of the Cox proportional hazards model predicting the hazard of first product introduction. The primary sample for this consists of 132 firms, 69 of which launched their first product during the period of observation. Model 1 presents the results with only the control variables included. In Model 2 and 3, I include the direct effect of venture knowledge complexity and founder pre-entry knowledge breadth respectively. In Model 4, I include the linear term for venture knowledge breadth, and in Model 5, I incorporate its squared term. In Model 6, I simplify the model by excluding the second order term for venture knowledge breadth and include the interaction between founder pre-entry knowledge breadth and venture knowledge complexity. In Model 7, I include the interaction between linear and squared

measures of venture knowledge breadth and venture knowledge complexity. Model 8 represents the full model where I include the interaction between founder pre-entry knowledge breadth and venture knowledge complexity as well as both linear and squared terms for venture knowledge breadth.

I interpret the results by considering both the statistical significance as well as the effect size. Table 2-3 provides the non-exponentiated coefficients. Here positive values indicate increase in the hazard rate of first product introduction, while negative values indicate decrease in the hazard rate of first product introduction. In other words, a positive coefficient would suggest that as the associated variable increases in value, there is a corresponding decrease in the time to first product introduction. Similarly, a negative coefficient would suggest that as the associated variable increases in value, there is a corresponding increase in the time to first product introduction.

Hypothesis 2 predicts that a firm's knowledge complexity will be negatively associated with the likelihood of first product introduction. In Model 2, the coefficient of the variable *Venture knowledge complexity* is negative and significant ($\beta = -.093$, $p<.05$), providing support for this hypothesis. Thus firms that have high knowledge complexity are less likely to successfully introduce their first product. Hypothesis 3a predicts that founders' knowledge breadth will be negatively associated with the likelihood of first product introduction. I test this hypothesis in Model 3. The coefficient of the variable is not significant ($p>.1$). Hence Hypothesis 3 is not supported. Hypothesis 3b predicts that venture knowledge complexity will have an inverted-U shaped relationship with the likelihood of first product introduction. I test for this hypothesis in Models 4 and 5. In Model 4, I add the first order term measure of venture knowledge complexity. The coefficient corresponding to this first order is positive but

marginally significant ($p<.1$). In Model 5, I examine the fit for a non-linear effect by adding the second-order term for venture knowledge complexity. Now, I find that the coefficient of the first order term is positive and strongly significant ($\beta = 0.317$, $p<.001$) while the coefficient for the second term is negative and significant ($\beta = -0.095$, $p < .05$). This provides strong empirical support for Hypothesis 3b.

Next, I consider the tests for the hypothesized interactions. Hypothesis 4a predicts that founders' knowledge breadth will moderate the negative relationship between venture knowledge complexity and likelihood of first product introduction such that high levels of knowledge breadth will strengthen the relationship, and conversely, low levels of knowledge breadth will weaken the relationship. I test this hypothesis in Model 6. The coefficient of the interaction term between founders' knowledge breadth and venture knowledge complexity is negative and significant ($\beta = -0.114$, $p<.01$). This provides weak support for the hypothesis. I examine this interaction in more detail in subsequent analysis. Hypothesis 4b predicts that the negative relationship between venture knowledge complexity and the likelihood of first product introduction will be moderated by venture knowledge breadth such that at higher levels of venture knowledge breadth, the negative influence of high knowledge complexity on first product introduction will be diminished. I test this hypothesis in Model 7 by including the interaction between venture knowledge breadth, its squared term and venture knowledge complexity. However, the interaction terms in Model 7 are not significant ($p>.1$). Hence Hypothesis 4b is not supported.

Model 8 represents the full model where I include the direct effects, the interaction effect between founders' knowledge breadth and both the linear and the squared terms for venture

knowledge breadth. The results of this model continue to support the results discussed so far. Next, I use these results to evaluate and discuss effect size associated with the relationships.

Economic Effects and Graphical Interpretation

To evaluate the effect size, I interpret the beta coefficient associated with the variable of interest to estimate the percentage change in the hazard rate as a function of changes in the value of the variable (Box-Steffensmeier & Jones, 2004: 60). For evaluating the direct effects, I consider the beta coefficients in Model 5 and for evaluating the interaction term, I consider the full model including the interaction (Model 8). Based on the results in Table 2-3 (Model 5), we see that a unit increase in knowledge complexity decreases the hazard of first product introduction by 8.8%.

The effect of venture knowledge breadth on the risk of first product launch is non-linear. To assess its economic significance, I consider the effect size of venture knowledge breadth at three points: at its mean value, at its mean + 1 standard deviation and at its mean – 1 standard deviation. By examining the coefficient of venture knowledge breadth, we note that when venture breadth is held at its mean minus one standard deviation, a unit increase in venture knowledge breadth leads to 24% increase in the risk of first product introduction. Holding venture knowledge breadth at the mean, a unit increase in venture knowledge breadth leads to 11% increase in the risk of first product introduction. However, holding venture knowledge breadth at the mean plus one standard deviation, a unit increase in venture knowledge breadth leads to 3.1% decrease in the risk of first product introduction. To further explicate this relationship, I plot this curvilinear effect in Figure 3-2. The upper and lower bound in the x-axis correspond to the range of values of venture knowledge breadth in my data. Values closer to 0 belong to firms that have low knowledge breadth while values closer to 4 represent firms on the

higher end of knowledge breadth. The plot shows that venture breadth of approximate 1.5 leads to the best chances of successful product introduction.

To interpret the interactive effect of founders' knowledge breadth and venture knowledge complexity on the hazard of first product introduction, I plot the interaction in Figure 2-3 to examine the nature of this relationship. The figure illustrates the effect on the hazard of product introduction across the entire range of venture knowledge complexity when founders' knowledge complexity is held at its mean and at one standard deviation above and below its mean. The figure shows that lower founders' knowledge breadth is associated with lower rate of decline in the hazard of product introduction with increasing venture knowledge complexity compared to the trend observed at higher levels of founders' knowledge breadth. I also calculate the economic effects for this interactive effect. I find that holding founder breadth at high (one standard deviation above the mean), when complexity is high (one standard deviation above the mean), there is a 32% reduction in the hazard of product introduction compared to when complexity is low (one standard deviation below the mean). On the other hand, holding founder breadth at low (one standard deviation below the mean), when complexity is high (one standard deviation above the mean), there is a 9% reduction in the hazard of product introduction compared to when complexity is low (one standard deviation below the mean). Similarly, holding knowledge complexity at high (one standard deviation above the mean), when founder breadth is high (one standard deviation above the mean), there is a 20% reduction in the hazard of product introduction compared to when founder breadth is low (one standard deviation below the mean). And finally, holding knowledge complexity at low (one standard deviation above the mean), when founder breadth is high (one standard deviation above the mean), there is a 7.5%

increase in the hazard of product introduction compared to when founders' knowledge breadth is low (one standard deviation below the mean). These effects are summarized in Figure 2-4.

Robustness Checks and Alternate model specification

As discussed previously, I also ran my analysis using an alternative model specification, the competing hazard model that offers the advantage of being able to control for the possibility of the competing event: a firm exit prior to its first product launch. The competing hazards model has been used to examine event history data by several scholars in recent management literature (e.g. Almandoz, 2012; Bakker & Shepherd, 2016; Raffiee & Feng, 2014; Upson, Ketchen, Connelly, & Ranft, 2012). In my analysis, using this analytical approach, the models failed to converge when I restricted my sample to the 132 firms with patent data. I then ran the models after removing this restriction i.e. by considering all firms in the sample regardless of whether or not they had patents. I addressed this underlying heterogeneity among the firms by including a dummy variable which was set to 1 for firms that did not have any patents but was otherwise set to 0. After this procedure, my sample for this analysis expanded to 156 firms. Out of these 156 firms, 80 launched their first product within the observation period, 16 experienced a competing event i.e.an exit prior to product launch and 60 were censored. The results from this analysis are summarized in Table 2-4.

In the competing risk models, interpretation of non-exponentiated coefficients is similar to that of the Cox proportional hazards model. Here, positive coefficients indicate that when the variable of interest increases, the hazard rate of experiencing the primary event i.e. first product introduction, increases compared to the base rate. In contrast, negative coefficients indicate that when the variable of interest increases, the hazard rate of experiencing first product introduction, decreases compared to the base rate. An examination of the results summarized in Table 2-4

show that no material differences manifested from this alternate specification – the results discussed previously in the primary analysis continue to hold.

To test for potential multicollinearity, I calculated the variance inflation factors (VIF) for the variables used in the analysis. Typically, VIF values less than 5 suggest that multicollinearity is not a concern in the model (Chatterjee, Hadi, & Price, 2000; Kennedy, 2008). I verified that this condition was satisfied by all models used in the analysis (mean VIF was 1.80 with a maximum VIF value of 3.91). This suggests that multicollinearity is not a serious problem in the analysis.

Table 2-1: Correlation Table

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Product Introduction	0.05	0.23	1													
2. Age	7.4	4.27	-0.12	1												
3. Boston	0.13	0.33	0	0.08	1											
4. Minneapolis	0.1	0.29	-0.01	-0.02	-0.12	1										
5. Bay Area	0.35	0.48	0.02	-0.04	-0.28	-0.24	1									
6. Orange County	0.08	0.27	-0.02	0.01	-0.11	-0.09	-0.21	1								
7. Number of founders	1.32	0.57	-0.03	-0.02	0.01	-0.06	0.1	0.01	1							
8. Alliance dummy	0.4	0.49	0.07	0.01	0.05	0.13	-0.12	-0.04	-0.17	1						
9. Venture knowledge complexity	0.61	0.83	-0.05	0.08	-0.07	-0.03	0.06	0.05	-0.06	0.09	1					
10. Founders' knowledge complexity (pre-founding)	0.46	0.59	-0.02	-0.1	0.02	-0.03	0.07	0.02	0.05	-0.09	0.07	1				
11. Founders' knowledge breadth (pre-founding)	0.62	0.9	-0.01	-0.05	0.01	-0.04	0.08	-0.02	0.02	-0.18	-0.04	0.38	1			
12. Venture knowledge breadth	0.54	0.79	0.03	0.08	-0.09	-0.04	0.01	-0.01	-0.13	0.22	0.48	0.08	-0.11	1		
13. Innovation team size	3.1	5.66	0.02	0.01	-0.11	-0.04	0.1	0.04	-0.07	0.16	0.5	0.1	-0.04	0.63	1	
14. Total funding received (lagged)	3.26	5.12	0.05	-0.03	0.02	0	0.03	-0.01	-0.1	0.05	0.2	0.12	0.04	0.19	0.15	1
15. Annual patent count (lagged)	1.89	4.11	-0.01	0.07	-0.09	-0.02	0.06	0.05	-0.07	0.09	0.62	0.11	-0.04	0.47	0.74	0.15

[a] Correlations equal to or greater than 0.20 are significant at the .05 level.

Table 2-2: OLS regression predicting the likelihood of Venture Knowledge Complexity

	Model 1	**Model 2**
Founders' Knowledge Complexity – **H1**		0.227***
		(0.046)
VC status	0.373***	0.384***
	(0.090)	(0.089)
Total funding	0.014**	0.014**
	(0.005)	(0.005)
Firm age	-0.061**	-0.061**
	(0.023)	(0.023)
Number of founders	0.083	-0.037
	(0.437)	(0.435)
Patent count	0.043***	0.042***
	(0.011)	(0.010)
Innovation team size	0.019+	0.019+
	(0.011)	(0.011)
Constant	-0.182	-0.069
	(0.483)	(0.481)
Firm dummies	Yes	Yes
Year dummies	Yes	Yes
Number of firms	132	132
R-Squared	0.2547	0.2693

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ()

Table 2-3: Cox Proportional Hazards Model predicting the hazard of first product introduction

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Venture knowledge complexity – **H2**		-0.061*	-0.062*	-0.076*	-0.093**	-0.048	-0.141+	-0.068*
		(0.031)	(0.031)	(0.035)	(0.033)	(0.031)	(0.085)	(0.032)
Founders' knowledge breadth – **H3a**			-0.072	-0.105	-0.118	0.042+	-0.107	0.044+
			(0.147)	(0.153)	(0.156)	(0.024)	(0.155)	(0.024)
Venture knowledge breadth – **H3b**				0.063+	0.317**	0.066+	0.327*	0.334**
				(0.037)	(0.108)	(0.037)	(0.138)	(0.120)
Venture knowledge breadth squared – **H3b**					-0.095*		-0.112+	-0.101*
					(0.042)		(0.062)	(0.048)
Venture knowledge complexity * Founder knowledge breadth – **H4a**						-0.114**		-0.129**
						(0.036)		(0.045)
Venture knowledge complexity * Venture knowledge breadth – **H4b**							0.034	
							(0.108)	
Venture knowledge complexity * Venture knowledge breadth squared – **H4b**							0.009	
							(0.043)	
Innovation team size	-0.002	-0.003	-0.002	-0.007	-0.012	-0.009	-0.014+	-0.013+
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.008)	(0.008)
Total funding	0.005	0.006	0.006	0.006	0.005	0.009*	0.005	0.007+
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Patent count	-0.004	0.004	0.004	0.006	0.010	0.008	0.010	0.011
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)	(0.010)
Firm age	-0.188	-0.192	-0.184	-0.131	-0.087	-0.152	-0.131	-0.098
	(0.118)	(0.119)	(0.120)	(0.144)	(0.128)	(0.143)	(0.119)	(0.126)
Number of founders	-0.330	-0.301	-0.308	-0.335	-0.374	-0.324	-0.367	-0.368
	(0.237)	(0.232)	(0.235)	(0.243)	(0.252)	(0.235)	(0.249)	(0.244)
Alliance indicator	1.111***	1.102***	1.069***	1.028***	1.050***	1.086***	1.062***	1.125***
	(0.229)	(0.231)	(0.250)	(0.254)	(0.256)	(0.254)	(0.256)	(0.259)
VC status	0.177	0.164	0.160	0.166	0.157	0.158	0.110	0.091
	(0.348)	(0.358)	(0.357)	(0.355)	(0.369)	(0.368)	(0.380)	(0.405)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of firms	132	132	132	132	132	132	132	132

Log likelihood	-259.8	-258.5	-258.4	-257.2	-254.8	-253.9	-254.3	-251.0
Chi2	84.13	92.55	110.9	123.04	156.3	105.1	163.6	147.7

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ()

Table 2-4: Competing Risks Model predicting the hazard of first product introduction

	Model 1	Model 2	Model 3	Model 4
Venture knowledge complexity – **H2**		-0.062*	-0.098**	-0.076*
		(0.030)	(0.034)	(0.032)
Founders' knowledge breadth – **H3a**		-0.091	-0.127	0.028
		(0.117)	(0.125)	(0.022)
Venture knowledge breadth – **H3b**			0.311**	0.322**
			(0.109)	(0.113)
Venture knowledge breadth squared – **H3b**			-0.092*	-0.095*
			(0.041)	(0.045)
Venture knowledge complexity * Venture knowledge breadth squared – **H4b**				-0.117**
				(0.043)
Innovation team size	-0.001	-0.002	-0.012	-0.012
	(0.007)	(0.007)	(0.008)	(0.008)
Total funding	0.005	0.006	0.005	0.007+
	(0.003)	(0.004)	(0.004)	(0.004)
Patent count	-0.004	0.005	0.011	0.012
	(0.010)	(0.011)	(0.010)	(0.010)
Firm age	-0.113	-0.104	-0.037	-0.043
	(0.118)	(0.117)	(0.107)	(0.102)
Number of founders	-0.297	-0.267	-0.304	-0.328+
	(0.186)	(0.187)	(0.201)	(0.192)
Alliance dummy	1.037***	1.002***	0.991***	0.987***
	(0.214)	(0.219)	(0.222)	(0.219)
VC status	0.153	0.133	0.119	0.137
	(0.330)	(0.339)	(0.353)	(0.373)
No patents dummy	0.021	-0.029	-0.061	-0.127
	(0.347)	(0.348)	(0.344)	(0.353)
Year dummies	Yes	Yes	Yes	Yes
Location dummies	Yes	Yes	Yes	Yes
Observations	156	156	156	156
Log likelihood	-326.7	-325.2	-321.2	-318.1
Chi2	1247	1316	1133	1193

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ()

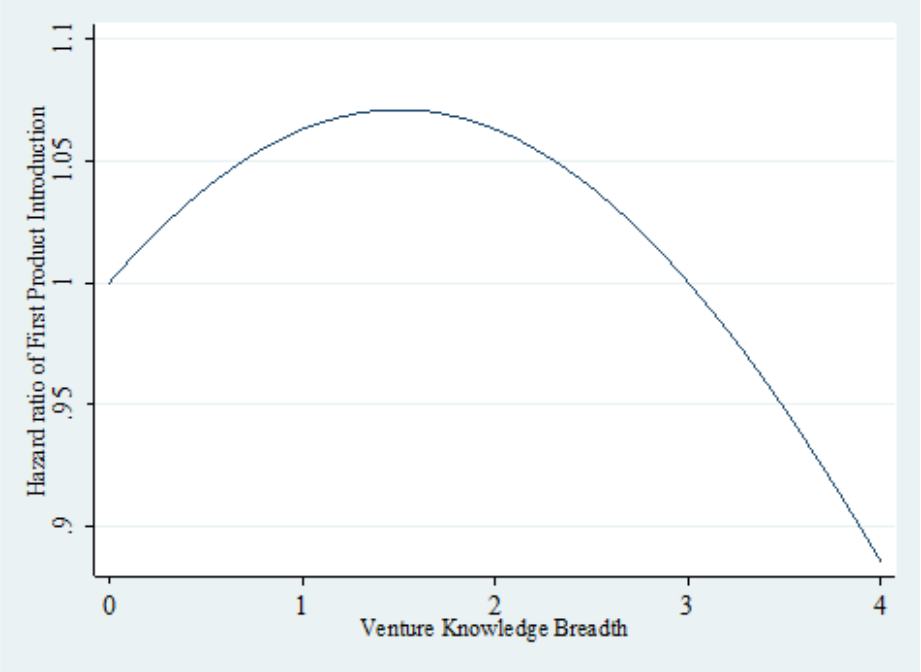

Figure 2-2: Curvilinear relationship between venture knowledge breadth and the hazard of first product introduction

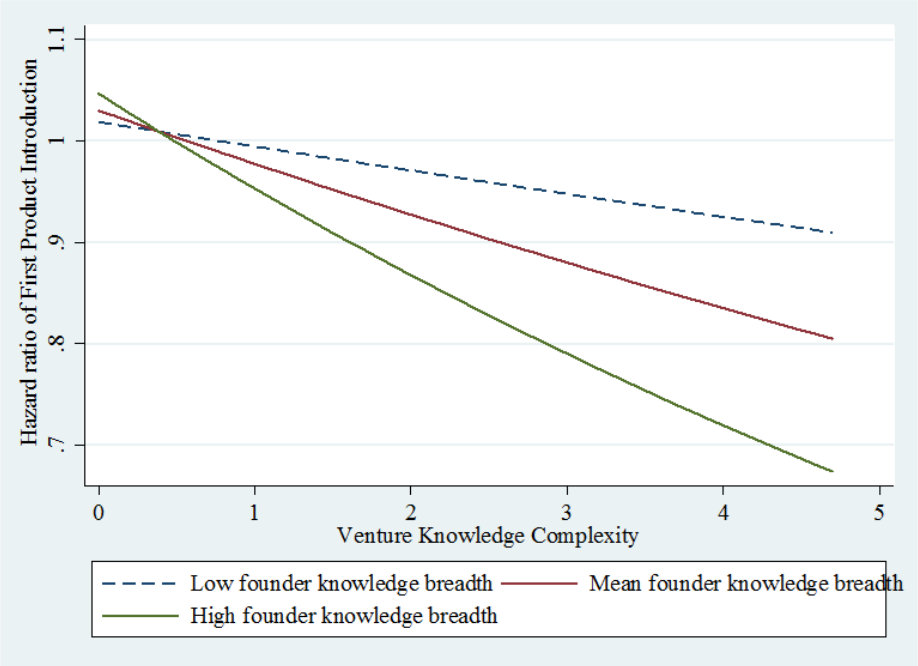

Figure 2-3: Interactive effect of venture knowledge complexity and founders' knowledge breadth on the hazard of first product introduction

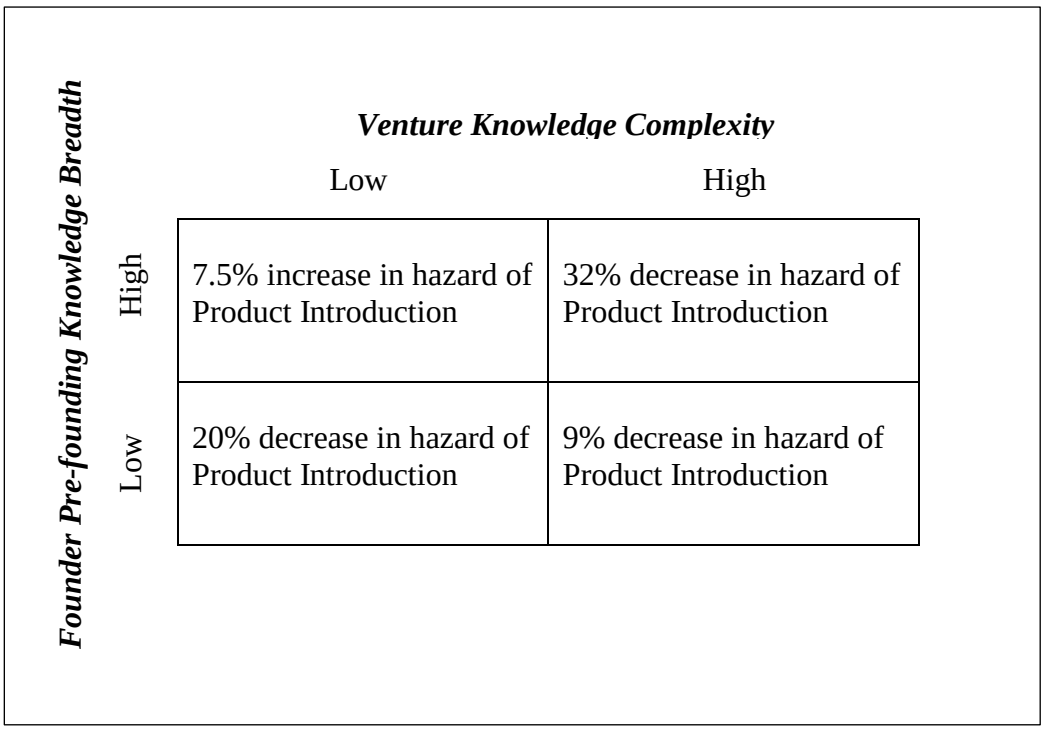

Figure 2-4: Summary of economic effect based on the interaction between venture knowledge complexity and founders' knowledge breadth

DISCUSSION

Being able to successfully introduce its first product marks a vital milestone in the life of a new venture. The launch of its first product provides a venture with a route to earning revenue and market share which can enable it to forge the path to legitimacy and financial independence. In high tech settings, founders often launch start-ups to commercialize their own inventions and ideas (Ganco, 2013; Gompers et al., 2005). However, very little is understood about how the structural characteristics of founders' knowledge can impact the performance of a new venture. In particular, I investigated how the extent of founders' knowledge complexity can imprint a venture's knowledge structure, and through this mechanism, impact the ability of the venture to successfully launch its first product. My findings deepen our understanding of the determinants

of successful product introduction by start-ups and shed further light on the deep and lasting relationship between founders and the ventures they create.

My findings contribute to the literatures on innovation, imprinting and entrepreneurship. I theorize and find evidence for the positive relationship between founders' knowledge complexity and the venture's knowledge complexity. This baseline finding provides clear evidence of the direct imprint of the founders' pre-founding knowledge structure on the ongoing knowledge creation by the new venture. I posit and find support for the hypothesis that there exists a negative relationship between venture knowledge complexity and the likelihood of a venture's first product introduction. This suggests that the influence of the founders' knowledge has a lasting impact not only on the venture's knowledge structure but also on the venture's eventual performance. I also contend but don't find empirical support for the hypothesis that founder pre-founding knowledge breadth has a net negative effect on a firm's performance. Although the direct effect of founder pre-founding knowledge breadth on firm performance is not supported, I find empirical support for the theoretical assertion that a venture knowledge breadth has an inverted-U shaped effect on the likelihood of a venture's first product introduction. This non-linear association provides additional evidence that firms, and especially start-ups, should be particularly watchful of the extent to which they engage in technological broadening. I also posit and show that founder pre-founding knowledge breadth moderates the direct effect of firm knowledge complexity on the likelihood of product introduction. This finding illustrates another important mechanism by which founder pre-founding knowledge can influence venture performance, far beyond the immediate effect. However, I do not find support for the contention that venture knowledge breadth moderates the relationship between venture knowledge complexity and the likelihood of first product introduction.

Some possibilities are consistent with the non-findings. First, as I argued in the hypothesis development for Hypothesis 3a, the effect of founders' knowledge breadth on firm performance involves both positive and negative influences. Although I probed the possibility of a non-linear relationship, I did not find evidence of it in empirical tests. Hence, one implication can be that the positive and negative direct effects of founder pre-founding knowledge breadth counteract each other, with a net effect that appears to be insignificant. However, as shown in Hypothesis 4a, this effect does manifest itself on venture performance through its interactive effect with venture knowledge complexity. Second, with reference to Hypothesis 4b, recall that increasing knowledge breadth is highly resource intensive and poses significant management challenges. Thus it is possible that increasing firm knowledge breadth is particularly problematic for start-ups who are typically significantly more resource constrained and attention-constrained than established firms. Thus the benefits of higher firm knowledge breadth for mitigating the negative effect of complexity may not be visible in case of start-ups. Future research that examines this relationship in the context of larger firms can clarify this matter. I now briefly touch upon the implications of this study for research and practice.

This study contributes important insights to the literature on founder imprinting and venture performance. While existing literature has primarily highlighted the lasting influence of early founder decisions pertaining to firm structure, early strategies and hiring decisions (for e.g., Beckman & Burton, 2008; Boeker, 1989; Burton & Beckman, 2007; Ding, 2011; Eesley et al., 2014), my findings draw attention to another important mechanism of founder imprinting that directly links attributes of founders' knowledge to venture knowledge creation and firm performance. In so doing, this study addresses the call for more research attention to the interaction between individuals and organizations engaged in the process of transferring and

recombining knowledge (Hsu & Lim, 2013). My findings complement existing research (e.g. Hsu & Lim, 2013) by showing that firms inherit their early knowledge search strategies from their founders while extending this research by illustrating that the adoption of search routines from founders may lead to a significant performance penalty for the firm if the founders' knowledge is complex. In addition, this study draws attention to the importance of founder pre-founding knowledge breadth towards determining the ability of the firm to successfully translate its knowledge structure into the launch of its first product.

My study contributes to the literature on innovation focusing on the association between breadth of technological search and firm performance (e.g. Dahlander et al., 2016; Ding & Eliashberg, 2002; Katila & Ahuja, 2002; Klingebiel & Rammer, 2014; Laursen & Salter, 2006; Leiponen & Helfat, 2010). While most of this prior research has focused attention on the firm's innovation performance measured using patent data, only a handful of studies (e.g. Katila & Ahuja, 2002; Klingebiel & Rammer, 2014; Ding and Eliashberg, 2002) have focused on performance indicators based on new product launch. In addition, while existing research has shown that a firm's internal search strategy has important repercussions on a venture's performance; this study is the first, to my knowledge, to examine the role of firm breadth in the context of new ventures with a focus on the likelihood of the firm to launch its first product. By drawing on a unique database that tracks firms in the MIS industry from the birth of the industry through 2007, I am able to shed new light on the relationship between firm breadth and firm performance. My finding pertaining to this relationship complements existing research (e.g. Katila & Ahuja, 2002; Laursen & Salter, 2006) that shows a curvilinear (inverted-U shaped) relationship between firm technological breadth and firm performance and adds a cautionary note to suggestions of expansion of a firm's knowledge portfolio (e.g. Ding and Eliashberg,

2002; Klingebiel & Rammer, 2014). My findings hold particular relevance to start-ups and early stage ventures that may be especially vulnerable to the downsides of excessive technological broadening.

Besides contributing insights to the innovation literature pertaining to the role of venture knowledge breadth, this study is the first to draw attention to the importance of founders' pre-founding knowledge breadth for determining venture performance. Although I don't find evidence of a direct association between founder pre-founding knowledge breadth and new venture performance, I find that founders' knowledge affects a start-up's performance by moderating the relationship between venture knowledge complexity and firm performance. While existing studies (e.g. Fleming & Sorenson, 2001; Gruber, Harhoff, & Hoisl, 2013a; Hargadon & Sutton, 1997) have highlighted the importance of a more diverse knowledge base for improving the effective of recombinatorial knowledge search, this study suggests that these advantages may not necessarily translate into innovation benefits (i.e. enabling successful commercialization of new products). While my findings support the notion that higher levels of founders' knowledge breadth may be advantageous, they suggest that these advantages primarily accrue at low levels of venture knowledge complexity. As a firm's knowledge complexity increases, the benefits of founder breadth diminish and in fact, turn negative. My results suggest that firms that engage in the production of complex knowledge experience significant performance benefits if their founders have specialized i.e. narrow technological breadth.

My findings also contribute important insights to the literature on entrepreneurship examining the role of founder pre-entry knowledge endowments on firm performance (e.g. Burton & Beckman, 2007; Dencker & Gruber, 2014; Fern et al., 2012; Gruber, MacMillan, & Thompson, 2013b). By examining the role of founders' knowledge structure on new venture

performance, this study sheds new light on a theoretical mechanism by which founder pre-entry knowledge impacts firm performance that has received little research attention. While several scholars (e.g. Colombo & Grilli, 2005; Gruber et al., 2013b) have highlighted the importance of a founder technological knowledge for shaping a venture's performance and choice of market opportunities, the relationship between the nature of this knowledge and a venture's ability to commercialize this knowledge has received little research attention. This study extends prior research (Ganco, 2013) that suggests that inventors with complex knowledge are likely to start new ventures. My findings suggest that founders who embrace entrepreneurship to commercialize complex knowledge may face an uphill battle translating the knowledge into a successfully commercialized product.

A better understanding of new product introduction is also valuable for practicing managers and founders of start-ups. This study underscores the importance of a focused knowledge strategy and highlights the dangers of embracing high levels of knowledge complexity. While complex knowledge provides important competitive advantages, it is also harder to manage and hence managers and founders need to be mindful of the need to achieve this balance in order to reap the advantages of complex knowledge.

Limitations and directions for further research

This study does have some limitations that should be addressed in future work. The empirical context for this study was a single industry. While the use of a single industry allowed me to control for many industry-specific, exogenous factors and technological conditions, it does limit the generalizability of these findings. Although I expect the findings of my study to hold for other knowledge intensive industries, the generalizability to other sectors and stages of venture life cycle should be examined in future research. Second, I used patent data to examine

characteristics of founder and venture knowledge. Since patenting propensities vary across industries (Cockburn & Griliches, 1987), their use also constrains the generalizability of the findings to industries where patenting is prevalent. As patenting is an important appropriability mechanism in the MIS industry, which is the empirical context of this study, this problem is mitigated in this study. Further, the use of a single industry context alleviates this problem as patenting propensity is likely to be stable within such a setting (Ahuja, 2000; Katila & Ahuja, 2002). Third, in this study, I study the impact of founder and firm knowledge characteristics on one important milestone of venture performance in terms of bringing its first product to market. While this is undoubtedly, an important and vital performance indicator of a start-up, this is but one of several important milestones in a venture's life. The economic performance of these products and their ability to drive a venture's successful exit is beyond the scope of this study. However, an examination of alternative measures is important because there may be trade-offs between different measures of firm performance. Future research should probe these important issues and investigate and compare alternative indicators of venture performance.

Conclusion

This study highlights the continuing importance and opportunities for deepening our understanding of founders' knowledge endowments and their effect on new venture performance. The findings also help to shed light on the pattern of connections between individuals and organizations engaged in the process of transferring and recombining knowledge to produce commercial products. By analyzing and highlighting some of the contingencies shaping the transformation of knowledge inputs to firm outputs, I suggest that there is still much to be learnt about the assets as well as the liabilities that founders bequeath to the ventures they found.

CHAPTER 3 - THE SHADOW OF THE PAST: EXAMINING THE INFLUENCE OF PRIOR FOUNDING EXPERIENCE ON LATER VENTURE SUCCESS

"My biggest piece of advice for entrepreneurs is to start that second venture, because you learn so much from your mistakes in the first…"

Oren Etzioni, Serial Entrepreneur and Professor of Computer Science

ABSTRACT

Do contexts that support innovation differ from those that support economic success? I examine this question in this study by examining how knowledge gained by a serial entrepreneur through prior entrepreneurial experience can have a differential impact on different indicators of firm performance. Drawing on the literature on innovation, learning and entrepreneurship, I hypothesize and find evidence that founder pre-entry knowledge can have differential effects on different types of firm performance indicators, thus revealing trade-offs in the effect of prior knowledge on firm performance. By focusing attention on two important types of founder pre-entry knowledge – technological knowledge and market knowledge and two indicators of firm performance – invention impact and economic success, this study uncovers important contingencies that shape the extent and nature by which prior experience translates into subsequent performance. I test my hypothesis using data on 334 VC-funded companies spanning six high-tech industry contexts in the United States.

INTRODUCTION

Serial entrepreneurs – those individuals who have owned or partly owned a business in the past and who then go on to found another new venture (Hyytinen & Ilmakunnas, 2007) – are often described as "economic artists -- bringing together economic resources rather than putting paint on canvas" (Chaplin, 2001). Their rich experience and deep knowledge of entrepreneurship enables serial entrepreneurs to recognize and act on opportunities (Politis, 2005), and they have a disproportionate impact on economic growth and job-creation (Eesley & Roberts, 2012; Hyytinen & Ilmakunnas, 2007) as compared to other entrepreneurs. Despite this recognition, serial entrepreneurship still remains an understudied phenomenon in academic literature (Eggers & Song, 2015; Hsu, 2007; Hyytinen & Ilmakunnas, 2007).

Studies in the management and entrepreneurship literatures have shown that prior entrepreneurial experience helps founders overcome the liability of newness (Stinchcombe, 1965) in ventures they create (Baron & Ensley, 2006; Delmar & Shane, 2006; Eesley & Roberts, 2012; Gruber, MacMillan, & Thompson, 2008; Paik, 2014). Such experience facilitates better knowledge of organizational processes that positively affects firm survival (Brüderl, Preisendörfer, & Ziegler, 1992). The knowledge gained through the venture founding process also develops entrepreneurs' cognitive ability and such entrepreneurs are likely to have a richer and more refined understanding of business opportunities than first-time entrepreneurs (Baron & Ensley, 2006). These capabilities result in a superior ability to recognize alternative business and market opportunities (Gruber et al., 2008; McGrath & MacMillan, 2000). Prior entrepreneurial experience also helps to develop valuable social capital and ease resource constraints. Research has shown that repeat entrepreneurs are more likely to leverage their pre-existing networks for recruiting talent (Aldrich Howard & Ruef, 2006; Rerup, 2005) and can more easily access venture capitalists for much needed start-up capital (Hsu, 2007; Shane & Cable, 2002). Finally,

prior founding experience is valuable not only when serial entrepreneurs have been successful in the past, but even when their previous ventures have failed. Experiencing failure enables entrepreneurs to recognize and be responsive to potential problems and avoid making the same mistake twice (McGrath, 1999; Rerup, 2005). In sum, this body of research suggests that prior entrepreneurial experience is likely to significantly improve later venture performance outcomes.

Nevertheless, some recent work has challenged this favorable view of prior entrepreneurial experience, and has provided evidence that prior experience per se may not translate into performance benefits (e.g. Eesley & Roberts, 2012; Gompers et al., 2010; Eggers & Song, 2015). This research supports the notion that knowledge acquired by learning is largely embedded in the context in which the learning occurs. Although we understand that experience interacts with context to create knowledge (Argote & Miron-Spektor, 2011) and that the value of acquired knowledge may be contingent on a venture's specific characteristics (Dencker & Gruber, 2014), our understanding of the ways in which experiential learning in different contexts impacts subsequent performance is very limited (Argote & Miron-Spektor, 2011; Muehlfeld, Rao Sahib, & Van Witteloostuijn, 2012).

The table below summarizes some key papers focused on prior entrepreneurial experience in the existing literature:

Table 3-1: Prior research on serial entrepreneurship

Study	Research Question	Data	Key Independent Variable	Dependent Variable	Key findings
Amaral et al. (2011)	How do individuals' general and specific human capital influence their decision to reenter entrepreneurship in a different (new or acquired) business, thereby becoming serial entrepreneurs?	Longitudinal database *Quadros de Pessoal* (Portugese database)	General human capital (education and paid employment experience), Specific human capital (experience in entrepreneurship, managerial attainment and founding experience)	Time from exiting one entrepreneurial experience to the start of the next entrepreneurial experience	Results suggest that general human capital has a negative effect on the hazard of becoming a serial entrepreneur while entrepreneur-specific human capital has a positive impact on the hazard of re-entering entrepreneurship.
Baron & Ensley (2006)	What are differences in pattern recognition between first time and repeat entrepreneurs?	Survey	Type of entrepreneur (novice/repeat)	Various cognitive prototypes	First time entrepreneurs much more likely to prioritize and emphasize innovation and novelty of the product/service compared to repeat entrepreneurs.
Dencker & Gruber (2014)	What is the role that opportunity plays in affecting new firm performance? How does the type of opportunity condition the relevance of the founder's distinct knowledge endowments when exploiting that type of opportunity?	Survey data (two waves)	(1) Industry specific risk (2) Entrepreneur industry experience (3) Entrepreneur managerial experience	Sales Revenue	The riskier the opportunity, the greater the performance of the start-up, above and beyond founder characteristics. Moreover, the value of founder knowledge is relative to the type of opportunity exploited: high-risk opportunities favor founders with managerial experience, whereas low-risk opportunities favor founders with industry experience.
Eggers & Song (2015)	What do serial entrepreneurs change between previous and current ventures based on the outcome of the previous venture, and what are the consequences of those changes?	Survey data	(1)Prior venture Success or failure (2) Industry change (3) Strategy change (4) Decision-making style change	Growth rate of current venture	Serial entrepreneurs whose previous venture failed are likely to blame the external environment and change industries to the detriment of their subsequent venture performance. By contrast, founders of failed ventures are unlikely to change aspects of their previous business (when starting their subsequent venture) that would be attributable to their leadership – strategy, decision-making, and planning style.

Eesley & Roberts (2012)	Is the superior performance of serial entrepreneurs due to their experience or talent? When is one more important than the other?	MIT alumni survey data (two waves)	(1) Entrepreneurial experience (2) Talent (3) Familiarity (Industry and technical)	Revenue	The relative importance of experience versus talent changes with the context. When the current market or technology is familiar, experience dominates. However, when the venture context is unfamiliar, talent is more important. Individuals with experience and talent handle both familiar and unfamiliar aspects and may extract more from a given level of experience.
Gruber et al. (2012)	How do founders' pre-entry knowledge and experience endowments shape an emerging firm's subjective market opportunity set (and consequently its strategic growth prospects)?	Survey data (single wave)	(1)Educational specialization diversity (2)Educational level diversity (3)Management experience (4)Marketing experience (5)Technological experience (6)Entrepreneurial experience	Number of market opportunities identified	Prior entrepreneurial and management experience endowments enhance, while marketing and technological experience endowments constrain, the number of market opportunities identified. In addition, the authors find that the number of market opportunities identified depends on the combinations of generalized and specialized endowments in the founding team.
Gruber et al. (2008)	Do serial entrepreneurs identify more market opportunities for their technologies prior to first entry? Do the identification of multiple market opportunities prior to first market entry leads to superior performance outcomes in new firm creation?	Survey data of VC-funded ventures	(1) Prior entrepreneurial experience (2) Mgmt. experience/Industry experience etc.	**(**1) Number of alternative opportunities identified (2)Yearly revenue of venture	Serial entrepreneurs learn to generate a "choice set" of alternative market opportunities before deciding which one to pursue in their new firm creation. Entrepreneurs who identify a "choice set" of market opportunities prior to first entry derive performance benefits by doing so and the relationship between the number of market opportunities identified prior to first entry and new firm performance is nonlinear and subject to decreasing marginal return.
Gompers et al. (2010)	Is there performance persistence in entrepreneurship? And, if so, why?	VentureSource data (multiple industries)	(1)Prior success/failure (2) market timing	(1)Next Venture Success (2)Pre-money valuations	Entrepreneurs with a track record of success are much more likely to succeed than first-time entrepreneurs and those who have previously failed. In particular, they exhibit persistence in selecting the right industry and time to start new ventures. Entrepreneurs with demonstrated market timing skill are also more likely to outperform industry peers in their subsequent ventures. This is consistent with the view that if suppliers and customers perceive the

					entrepreneur to have market timing skill, and is therefore more likely to succeed, they will be more willing to commit resources to the firm.
Hsu (2007)	What are the correlates of varied sourcing and valuation of VC funding among entrepreneurs with disparate backgrounds, factoring in prior founding experience, academic training and social capital in VC funding?	Survey	(1) Direct tie to VCs (2) Prior entrepreneurial experience (3) Social capital of founders	(1) Likelihood of VC funding (2) Amount of VC Valuation	Prior founding experience (especially financially successful experience) increases both the likelihood of VC funding via a direct tie and venture valuation. Second, founders' ability to recruit executives via their own social network (as opposed to the VC's network) is positively associated with venture valuation. In the emerging (at the time) Internet industry, founding teams with a doctoral degree holder are more likely to be funded via a direct VC tie and receive higher valuations, suggesting a signaling effect.
Hyytinen & Ilmakunnas (2007)	(1) Whether individuals who are currently not entrepreneurs but who have past experience as an entrepreneur have more aspirations than others to start a (new) business of their own and (ii) controlling for such aspirations, whether they have a higher probability of actually transiting into entrepreneurship.	Longitudinal survey data	Prior entrepreneurial experience	(1) Aspiration (2) Transition to entrepreneurship	Serial entrepreneurship accounts for nearly 30% of the transitions from paid employment into entrepreneurship. Having worked in the past as an entrepreneur increases both the probability that a person presently in paid employment aspires to again become an entrepreneur and, holding the aspirations constant, the probability of her again becoming an entrepreneur.
Paik (2014)	How does prior entrepreneurial experience affect subsequent venture performance?	VentureSource database	(1)Prior VC financing (2)Prior success	Firm survival	Ventures founded by serial entrepreneurs perform better than those founded by novice entrepreneurs regardless of whether entrepreneurs had prior success or failure. However, contrary to expectations, this study finds that serial entrepreneurs without prior VC financing experience perform better than serial entrepreneurs with prior VC financing experience, suggesting that there may be an inadvertent cost of learning about the VCs.
Shane & Cable (2002)	How do seed-stage investors select which ventures to fund?	Survey	(1)Social ties (2)Reputation	Investment Decision	Social ties provide an important mechanism through which information asymmetry is overcome in venture finance.

Shepherd et al. (2009)	Why do owner-managers delay business failure when it is financially costly to do so?	None	Financial cost of failure Emotional Cost of failure	Overall Recovery	Under some circumstances delaying business failure can help balance the financial and emotional costs of business failure to enhance an owner-manager's overall recovery — some persistence may be beneficial to recovery and promote subsequent entrepreneurial action.
Toft-Kehler et al. (2014)	Why increasing entrepreneurial experience does not always lead to improved financial performance of new ventures?	Longitudinal Swedish databases (RAMS and LISA)	(1)Number of ventures founded (2) Industry similarity (3) Geography similarity (4) Temporal similarity	Entrepreneurial earnings	Superior financial performance only occurs at substantial levels of experience. Found that contextual similarities among prior and current ventures, such as industry, geographic, and temporal characteristics, positively moderated the direct experience-performance relationship.
Ucbasaran et al. (2010)	Does entrepreneurial business ownership experience dampens or promotes comparative optimism?	Survey	(1)Experience of business failure (2) Type of entrepreneur (serial or portfolio)	Entrepreneur's comparative optimism	Experience with business failure was associated with entrepreneurs who are less likely to report comparative optimism. Portfolio entrepreneurs are less likely to report comparative optimism following failure; however, serial entrepreneurs who have experienced failure do not appear to adjust their comparative optimism.
Ucbasaran et al. (2009)	What is the nature of the relationship between an entrepreneur's business ownership experience and the number of opportunities for creating or purchasing a business identified in a given period? How does an entrepreneur's business ownership experience relate to the innovativeness of the opportunity exploited?	Survey	(1) Total number of businesses founded (2) Number of failures as a proportion to total foundings	(1)Opportunity Identification (2) Innovation	Experienced entrepreneurs identified more opportunities and exploited more innovative opportunities with greater wealth creation potential. Entrepreneurs that had owned more than 4.5 businesses, however, identified fewer opportunities. The nature of prior business ownership experience also shaped opportunity identification behavior. An inverse U-shaped relationship was detected between the proportion of failed businesses relative to the number of businesses owned and the number of opportunities identified in a given period. Business failure experience was not associated with the innovativeness of exploited opportunities.

Experience is known to be a poor teacher (Levinthal & March, 1993; March, 2011), with lessons that are often hard to interpret. Scholars have highlighted the dangers of 'superstitious learning' and 'competency traps' (Levitt & March, 1988), where decision-makers either fail to learn, or draw inappropriate lessons from their prior experiences. The context specificity of learning has led scholars (e.g. Katila & Shane, 2005) to question whether contexts that support innovation might differ from those that support firm financial success. I investigate this issue in this study by examining whether prior experience can affect a firm's innovation performance and economic performance differently. In this study, I draw on learning theory as it relates to transfer of learning across contexts (e.g. Finkelstein and Haleblian 2002), innovation literature related to technology recombination for innovative performance (e.g. Hargadon and Sutton, 1997) and entrepreneurship literature related to the role of founder's knowledge in affecting new venture performance (e.g. Dencker & Gruber, 2014) to infer how knowledge gained by a serial entrepreneur through prior entrepreneurial experience can have a differential impact on different indicators of firm performance.

Scholars of entrepreneurship have made a distinction between technology-based ventures and other entrepreneurial endeavors. Technology-based ventures place a greater emphasis on science and technology as the basis of entrepreneurial opportunity (Beckman, Eisenhardt, Kotha, Meyer, & Rajagopalan, 2012) and are notable for their exceptional potential for growth and competitiveness (Hsu, 2008). In this study, I focus on technology-based ventures and examine how heterogeneity in two key contexts – choice of technology and market, across successive ventures started by serial entrepreneurs, impact venture performance. I measure performance by examining both the invention impact of the venture and its likelihood of achieving a successful exit. I measure invention using a widely used measure that indicates contribution to

technological progress, the number of forward citations received by a patent (Hall, Jaffe, & Trajtenberg, 2005) and I measure successful exit as an exit achieved either through an initial public offering or a successful acquisition (Arora & Nandkumar, 2011). I test the hypotheses on a sample of 334 venture capital (VC) funded entrepreneurial ventures started by serial entrepreneurs from 1990 to 2005, spanning six knowledge-intensive industries.

The findings of this study have important implications for both theory as well as practice. Studies examining the implications of prior experience have typically either focused attention on its learning implications (e.g. Gompers, Kovner, Lerner, & Scharfstein, 2010; Toft-Kehler, Wennberg, & Kim, 2014) or on the derived resource benefits (e.g. Hsu, 2007; Shane & Cable, 2002; Shane & Stuart, 2002). This study contributes to this literature by combining these perspectives to understand how contingencies shape the extent and nature by which prior experience translates into subsequent performance and furthers the research agenda by offering a more nuanced understanding of when and how heterogeneity in learning contexts impacts subsequent performance (Argote & Miron-Spektor, 2011) in entrepreneurship (Corbett, 2007; Holcomb, Ireland, Holmes Jr, & Hitt, 2009; Krueger, 2007). My findings contribute to the literature on serial entrepreneurship by drawing attention to the fundamental trade-offs that serial entrepreneurs face when they pick key contexts for their ventures and continues to support the notion that learning in the entrepreneurial context is not a simple or linear process (Hsu, 2007; Eggers & Song, 2015; Eesley & Roberts, 2012; Toft-Kehler et al., 2014). In particular, while prior studies have primarily focused on the positive impact of accumulation of market knowledge on firm performance, this study extends this literature by showing that extensive knowledge endowments can impact performance in both positive as well as negative ways. My findings also contribute to the literature on founder pre-entry knowledge (Burton & Beckman,

2007; Dencker & Gruber, 2014; Fern, Cardinal, & O'Neill, 2012) by shedding light on the relationships between two important types of founder pre-entry knowledge - technological knowledge and market knowledge, and explicating their impact on two important indicators of firm performance.

This study contributes to practice by drawing attention to the ways in which an entrepreneur's prior entrepreneurial experience can be leveraged to shape key strategic aspects of the later venture such as choice of technology and market that ultimately determine the performance of that venture. The findings also provide a new perspective to the important debate on the merits and efficacy of prior entrepreneurial experience that has engaged scholars as well as practitioners interested in entrepreneurship.

THEORY AND HYPOTHESES

The vast majority of entrepreneurial ventures in most industries end in failure (Dunne, Roberts, & Samuelson, 1988). This 'liability of newness' (Stinchcombe, 1965) has been attributed to new ventures' comparative disadvantage by way of lacking legitimacy, knowledge of the environment and access to resources relative to more established ventures. Both environmental and organizational elements at founding play a critical role in stacking the deck against new ventures. At the environmental level, selection forces often favor incumbent firms who have established legitimacy and have higher levels of reliability in their performance, routines and structures (Hannan & Freeman, 1984). At the organizational level, a new venture lacks established routines to guide its behavior (Nelson & Winter, 1982). Therefore, new ventures need to invest scarce resources in devising new routines and forging new exchange relationships based on a trial and error process that greatly increases the risk of failure (Stinchcombe, 1965; Nelson and Winter, 1982).

Prior founding experience can significantly help ventures to overcome the liability of newness. First, prior entrepreneurial experience enables founders to have better knowledge of organizational processes that effect firm survival. Much of this knowledge is tacit and cannot be substituted by other kinds of learning (Delmar & Shane, 2006). For example, new venture founders often encounter difficulties with finding capital, hiring workers, choosing the appropriate market, establishing contacts with potential customers and developing new products (Aldrich Howard & Ruef, 2006; Brüderl et al., 1992). Founders are also often unaware of what roles are necessary to run organizations efficiently and how to identify the appropriate people for those roles (Brüderl et al., 1992). The rich set of experiences founders gain through the course of their maiden venture provides them with a wealth of information, knowledge and guidelines pertaining to the venture founding process that they can subsequently apply to their next venture and greatly mitigate many of the hazards of founding (Shepherd, Douglas, & Shanley, 2000).

Second, as shown by Baron and Ensley (2006), the knowledge gained through the venture founding process develops entrepreneurs' cognitive ability and such entrepreneurs are likely to have a richer and more refined cognitive representation of business opportunities than first-time entrepreneurs. Baron and Ensley (2006) find evidence that first-time entrepreneurs are more likely to be caught up in the excitement of new business creation and pay excessive attention to attributes such as the novelty or uniqueness of the new venture at the expense of more mundane but mission critical factors related to actual business processes and conditions (for example, attaining positive cash flow and time to break even) that are likely to have a stronger impact on new venture outcomes. This cognitive development confers benefits such as enabling serial entrepreneurs to recognize alternative business and

market opportunities (Gruber et al., 2008; McGrath & MacMillan, 2000). For example, McGrath and MacMillan (2000) find that serial entrepreneurs develop and employ "opportunity registers" which are active repositories of potential business opportunities that enable such entrepreneurs to have a choice-set of ideas to exploit when the time is right. Similarly, Gruber and colleagues (2008) find empirical evidence that serial entrepreneurs have superior insights on the technology-to-market linking problem in new firm creation compared to first-time entrepreneurs and identify a larger number of market opportunities. Further, they find that identification of a greater number of opportunities is associated with superior performance, as measured by sales revenue. Taken together, these studies offer evidence that shows that founding experience significantly develops entrepreneurs' cognitive ability in ways that make tangible positive contributions to improving new venture outcomes.

Third, prior entrepreneurial experience helps to develop valuable social capital. Research has shown that repeat entrepreneurs are more likely to have direct ties to venture capitalists which greatly improves their chance of obtaining venture capital (Hsu, 2007; Shane & Cable, 2002), hiring workers based on their pre-existing network of ties (Rerup, 2005) and ultimately enhances their chances of success (Shane & Cable, 2002).

Finally, it has been argued that the value of this prior experience is not conditional on the success of the venture and that even a failed venture provides immense utility by way of its didactic potential. Failure usually provides clearer causal linkages between actions and outcomes compared to success and thus can be expected to impart a higher level of learning about the entrepreneurial process than that derived from success (McGrath, 1999).

While it is clear that prior entrepreneurial experience can provide benefits, recent research findings suggest that the realization of these benefits may be subject to certain

conditions. For example, Eesley and Roberts (2012) find evidence that prior entrepreneurial experience predicts success for a startup only when the experience has been obtained in industry conditions similar to the startup's industry. Gompers and colleagues (2010) evaluated venture capital backed serial entrepreneurs and found that it is only successful founders (and not most entrepreneurs, on average) who seem to significantly improve the likelihood of success of their later ventures compared to first-time entrepreneurs. Similarly, Eggers and Song (2015) show that the benefit of prior entrepreneurial experience disproportionately accrue to entrepreneurs who pick the same industry context across successive ventures. Since experience interacts with context to create knowledge (Argote and Miron-Spektor, 2011), it is important to discern the contingencies that impact the relationship between prior entrepreneurial experience and venture performance. In this study, I examine the importance of prior experience by focusing on changes in two key contexts relevant to entrepreneurship. These are: (a) a serial entrepreneur(s)' choice of technology and (b) market context across the prior and later ventures. Before turning to this, I briefly discuss the unique importance of technology and market contexts for entrepreneurial ventures.

Significance of technology and market contexts for new venture performance

Scholars of entrepreneurship have identified two primary risks that technology ventures face: technology risk and market risk (Fisher, Kotha, & Lahiri, 2015; Kazanjian, 1988). Technology risk, which deals with critical technological challenges underlying a venture's product offering, is dominant in the early stages of a venture's life. Market risk, on the other hand, refers to the uncertainties arising from competitors and consumer responses along with other environmental factors that impact venture performance. As the venture resolves the critical technological challenges underlying its product and transitions into more

mature stages, its technology risk is mitigated and its market risk becomes dominant. The technology and market focus of a firm are the primary drivers that directly influence the associated risks and impact a firm's performance. As Wiklund and Shepherd (2003: p.1308) note, "Knowledge about markets and technology represent two strands of procedural knowledge that potentially have strong performance implications, because… they increase the ability to discover and exploit opportunities." I discuss each of these two types of knowledge contexts next, starting with technology.

Technological knowledge. For technology ventures to grow, they need to constantly create new knowledge (Kogut & Zander, 1996). Technological knowledge is "a systematic body of knowledge about how natural and artificial things function and interact" (Itami & Numagami, 1992: p.119). Technological knowledge facilitates invention and may lead firms to develop radical breakthroughs even where their market viability is unknown (cf. Abernathy & Utterback, 1978). Technological knowledge enhances firm competitiveness by enabling them to maximize product performance through finding the optimal combination of functionality, cost, and reliability (Rosenberg, 1994) and by improving firms' ability to respond to product improvements by competitors (Cohen & Levinthal, 1990).

The process of creating new technological knowledge is achieved by either searching for and recombining knowledge components proximate to the existing knowledge of the new venture i.e. local search; or recombining components from different, often sparsely connected domains i.e. distant search (Rosenkopf & Almeida, 2003). The initial knowledge search strategy adopted by founders of new ventures has been shown to have significant implications for establishing the firm's ongoing organizational innovation search trajectory through imprinting, and eventually driving important venture performance outcomes (Hsu & Lim,

2013). In sum, technological knowledge can influence an entrepreneur's ability to discover opportunities, execute strategies and grow technology-based ventures, and thus represents an important knowledge-based resource for a firm.

Market knowledge. Market knowledge[1] refers to knowledge pertaining to the target market arising from direct contact with the market and the knowledge of customer wants, needs, and processes (Cooper, Folta, & Woo, 1995; Wennberg, Wiklund, & Wright, 2011; Wiklund & Shepherd, 2003). Users of new technologies are unlikely to be able to articulate their needs, and hence an entrepreneur's understanding of what the customer needs is often the basis of real market opportunities (Shane, 2000). For example, Shane (2000) studied how the same technology 3DPTM, licensed by MIT, was commercialized in 8 different markets, depending on heterogeneity across entrepreneurs' assessment about the potential market for the technology. Moreover, an understanding of customer needs and willingness to pay enables an accurate assessment of the attractiveness of entrepreneurial opportunities (Kirzner, 1997). Indeed, prior research has indicated that a key source of advantage for serial entrepreneurs lies in their ability to generate a "choice set" of alternative market opportunities for their subsequent venture (Gruber et al., 2008).

Higher levels of market knowledge also provide firms with superior ability to develop the right products for their target market (Narver & Slater, 1990). Familiarity with the target market provides entrepreneurs with important insights into valuable industry-specific knowhow such as important technologies, prevalent business strategies, competitive landscape, employment practices, customer preferences, familiarity with suppliers and

[1] In this study, the terms market and industry are used interchangeably. There is little written about the distinction between the two concepts in the literature though scholars have noted that 'industry' is typically used to focus on production and is more often associated with the supply side while 'market' is used to focus on users and is more often associated with the demand side (Curran & Goodfellow, 1990; Nightingale, 1978).

distributors etc. (Cooper, Gimeno-Gascon, & Woo, 1994; Helfat & Lieberman, 2002). These insights which usually constitute tacit knowledge are often vital for successfully exploiting an opportunity and are not likely to be available to outsiders inexperienced with the industry's norms (Delmar and Shane, 2006). In addition, such individuals are likely to possess ties to key actors associated with the market such as potential suppliers, distributors, channel partners and customers. Such ties can be invaluable for securing their commitment as well as garnering legitimacy in the eyes of important stakeholders such as financial resource providers (Delmar and Shane, 2006). In sum, the findings in the literature indicate that an entrepreneur's extent of market knowledge has important implications for a venture's performance.

Serial entrepreneurs, however, can and often do choose significantly different contexts across their ventures (Eggers & Song, 2015; Gompers et al., 2010). Since learning is context-specific (Glynn, Lant, & Milliken, 1994), the question arises whether the learning that benefits performance in one area can lead to trade-offs in performance in another area. An examination of this issue enables us to develop a more fine-grained understanding of the relationships between different types of learning and their eventual impact on firm performance. I consider two indicators of performance in my analysis: (i) invention impact, and (ii) economic success, demonstrated by a successful venture exit.

Impact of technology and market relatedness on invention impact

Invention is the task of successfully developing a new idea or an act of creation (Hitt, Hoskisson, & Nixon, 1993: 162). The value of an invention is typically determined by the extent to which it serves as prior art for subsequent inventions (Harhoff, Narin, Scherer, & Vopel, 1999; Trajtenberg, 1990). While most inventions make no impact, the ones that do, generate great value for society and serve as a harbinger for technological progress (Scherer & Harhoff, 2000).

From the technological standpoint, invention is often conceptualized as a recombinatorial search process (Dosi, 1988) that involves solving problems by either creating new combinations of existing knowledge elements (Fleming, 2001; Nelson & Winter, 1982) or reconfiguring previously combined knowledge elements in a novel way (Henderson & Clark, 1990). The process of recombination can involve either local search or distant search.

The strategy of local search involves identifying promising combinations of knowledge components in the vicinity of an entity's existing knowledge base (Stuart & Podolny, 1996). Local search help to mitigate uncertainty and improves reliability of outcomes by focusing the search on known, well-tried directions as opposed to searching in uncertain, new directions (Katila & Ahuja, 2002). Engaging in local search enables building of expertise through incremental innovations in a narrow search domain. Such focus may facilitate the creation of a distinct competence and have performance benefits (Rosenkopf & Nerkar, 2001). Over time, however, such focus may also lead to the development of 'core rigidities' (Leonard-Barton, 1995) or 'competency traps' (Levitt & March, 1988), potentially negatively impacting the ability to achieve successful recombination.

Distant search, on the other hand, involves greater exploration to find appropriate combinations of knowledge elements that the new venture could utilize (Ahuja & Morris Lampert, 2001; Rosenkopf & Nerkar, 2001). By exposing firms to new knowledge from unfamiliar domains, it encourages exploration and helps individuals and organizations avoid premature adoption of sub-optimal world-views (Levinthal & March, 1993), a problem that may be especially detrimental for performance in case of organizations whose knowledge is at an early formative stage (Audia, Locke, & Smith, 2000; Levinthal & March, 1993). However, while increasing a venture's ability to develop novel knowledge; distant search is

also fundamentally mean decreasing i.e. the high probability of failure conspires to lower the average success that can be expected using this strategy.

In case of serial entrepreneurs, those who found later ventures in technological contexts that are similar to their prior ventures, utilize local search, and are thus likely to suffer from concomitant issues of reduced creative exploration of new ideas, thus reducing the likelihood of creating impactful inventions. On the other hand, serial entrepreneurs who found their later ventures in distant technological contexts compared to their prior venture utilize distant search, which is likely to involve a high level of trial and error, and it would also consequently decrease the likelihood of achieving a high invention impact.

In sum, I argue that although there is an initial positive relationship between the extent of technology relatedness between successive ventures founded by a serial entrepreneur and the potential for invention impact, this effect could reverse and turn negative when the extent of relatedness between the two successive ventures is too great. I thus posit that some relatedness, but not too much, between the technological contexts of successive ventures is often desirable. Based on the above arguments, I would expect the existence of an inverted-U shaped relationship between the extent of technology relatedness between the prior and later ventures of the serial entrepreneur and the invention impact of the later venture. This leads to my first hypothesis:

Hypothesis 1a: *Technology relatedness between prior and later ventures has a curvilinear (inverted-U shaped) relationship with the likelihood of later venture invention impact.*

I contend that market knowledge, in contrast to technological knowledge, is likely to negatively impact inventive search. Entrepreneurs who possess high levels of market

knowledge are likely to have a better understanding of how to meet customer demand and a rich understanding of the advantages and disadvantages of various products and services in the market (Delmar & Shane, 2006). While such knowledge is advantageous in enabling the entrepreneur to identify and pursue untapped market opportunities, it is also likely to encourage them to remain embedded in market traditions and practices and to adopt familiar market routines and norms. But many scholars have argued that innovation is most likely to be achieved when individuals and organizations can escape established logics (e.g. Austin, Devin, & Sullivan, 2012; Merton & Barber, 2004). Thus founders who have a high level of market knowledge are less likely to pursue an innovation focused strategy.

Indeed, a similar pattern was observed by Baron and Ensley (2006) who examined the cognitive frameworks for opportunity evaluation employed by experienced and inexperienced entrepreneurs. They found that experienced entrepreneurs are likely to be strongly focused on operational issues (e.g., meeting customer needs, generating cash flow, manageable risk, etc.) and are less focused on innovation-specific considerations such as novelty of the idea, superiority of the product/technology or potential to change the industry. However, this pattern was reversed for inexperienced entrepreneurs who appeared to emphasize innovation-specific considerations at the expense of operational issues. Similarly, Ruef (2002) found that experienced entrepreneurs are more likely to pursue incremental as opposed to radical inventions. Taken together, these studies suggest that increasing knowledge of markets and entrepreneurship may come at the cost of decreasing incentives to innovate.

I posit that the negative effect of experience on innovation-specific considerations is likely to be contingent on the extent of market knowledge of the entrepreneur. Specifically, I argue that the negative influence of market knowledge on innovation is likely to be directly

proportional to the extent of market relatedness between the prior and later venture of a serial entrepreneur. Lower market relatedness is likely to encourage entrepreneurs to challenge existing ways of operating and thinking, thereby encouraging creative insights. As Aldrich and Kenworthy (1999) note, "[I]ndifference to industry routines and norms gives an outsider the freedom to break free of the cognitive constraints on incumbents", making innovations more likely. Indeed, research on creativity suggests that exposure to multiple domains and contexts and enables individuals to break perceptual set (Katona, 1940), avoid "functional fixedness" (Duncker, 1945), explore new cognitive pathways by increasing one's "network of possible wanderings" (Newell & Simon, 1972) and critically peruse well-used performance "scripts" (Amabile, 1998). Thus, lower levels of market relatedness across successive venture contexts is likely to enable serial entrepreneurs to promote innovation whereas, serial entrepreneurs who found later ventures with high levels of market relatedness are likely to become constrained by the familiar and are more likely to adhere to conventional technologies and ideas.

In sum, while greater market familiarity arising from higher levels of market relatedness across successive ventures contexts is likely to lead entrepreneurs to engage in the safety of tried and tested technologies and incremental inventiveness, lower levels of market relatedness may promote creative insights, with the potential of high inventive impact. Hence I expect that lower market relatedness between the prior and the later venture is likely to bolster the invention impact of the new venture. Conversely, high levels of market relatedness between the prior and the later venture is likely to negatively influence the invention impact of the venture. This leads to the following hypothesis:

Hypothesis 1b: *Market relatedness between prior and later ventures has a negative relationship with the likelihood of later venture invention impact.*

Impact of technology and market relatedness on likelihood of economic success

Achieving economic success through a favorable exit, however, calls for a different set of strategies compared to invention success. Economic success is more likely to follow from the introduction of "template-based" ideas (Goldenberg, Lehmann, & Mazursky, 2001) that typically involve making only incremental changes to well established technologies that align well with customer mental models thus easing their legitimacy. These ideas are therefore deeply embedded in specific markets and technologies and are more likely to reward appropriate replication of previously learnt strategies which, in case of serial entrepreneurs, is likely to be associated with greater relatedness between successive venture contexts.

Prior research has indicated that several advantages arise from relatedness across successive business ownership task experiences for venture performance. For example, relatedness across successive venture contexts improves the ability of serial entrepreneurs to leverage their prior entrepreneurial experience (Eesley & Roberts, 2012) and improves an entrepreneur's ability to discover and exploit opportunities (Rerup, 2005). Research on entrepreneurial learning has shown that what is learnt through entrepreneurial experience are problem solving strategies called heuristics (Bingham & Eisenhardt, 2011). The context-specific nature of heuristics (March, 2011) makes them likely to be ineffective, or worse, counterproductive, if applied to situations that are out-of-context. The idea of 'negative transfer' (Bartlett, 1958) in the psychology literature is used to refer to the transfer of learning from prior experience to dissimilar contexts, with detrimental results. For example, Finkelstein and Haleblian (2002) find that when firms enter into their second acquisitions in an industry different

from their first, the later acquisition tends to underperform the first. In sum, I posit that the extent of technology and market relatedness across the prior and later ventures of a serial entrepreneur is likely to impact the likelihood of the venture achieving economic success. This leads to the following two hypotheses:

Hypothesis 2a: *Technology relatedness between the prior venture and the later venture has a positive relationship with the likelihood of later venture economic success.*

Hypothesis 2b: *Market relatedness between the prior venture and the later venture has a positive relationship with the likelihood of later venture economic success.*

My arguments so far have focused on the direct effects of technology and market relatedness between a serial entrepreneur's successive ventures on the later venture performance. Next, I consider the interactive effect of the two contexts on later venture performance.

Interactive effect of technology and market relatedness on later venture performance

I have previously theorized that technology relatedness has a curvilinear relationship with later venture invention impact, and that market relatedness negatively influences later venture invention impact as ventures characterized by high market relatedness are more likely to be focused on addressing a specific market need and are likely to have lower strategic focus on developing novel inventions. I now posit that the rate of decrease of invention impact is likely to be a function of the level of market knowledge of the serial entrepreneur.

Entrepreneurs with high level of market knowledge are less likely to be motivated to seek to be technologically innovative. Prior research has shown that markets are more likely to favor products that incorporate existing technological technologies in novel ways than to favor new technological breakthroughs. For example, Goldenberg, Lehmann & Mazursky (2001: p.73) note

that, “[T]he market favors innovative products that do not require major adjustments to produce them. This market preference can be termed “secure progress”—by rejecting highly complex products, the market exerts pressure on companies to produce new products based on existing resources and technology.” This notion of ‘secure progress’ suggests that entrepreneurs with deep knowledge of the market focus of the venture have a strong incentive to seek to incorporate well accepted and understood technologies to satisfy the perceived market gap. Hence firms started by these entrepreneurs are likely to engage in a significantly more constrained search for technological knowledge and insights.

Although technological relatedness can improve the ability of the firm to successfully recombine knowledge and create impactful knowledge, these benefits last only up to a point. At high levels of technology relatedness, entrepreneurs engage in local search for knowledge creation (Rosenkopf & Nerkar, 2001). However, this process of recombining familiar knowledge elements is eventually counterproductive as the number of possible combinations diminish and fewer new ideas emerge from the limited set of knowledge elements (March, 1991), thereby leading to diminished invention impact. Entrepreneurs with high market knowledge are then more likely to engage in local search and search familiar knowledge domains to stay within the bounds of the market preference for ‘secure progress’.

Conversely, at low levels of technology relatedness, entrepreneurs engage in distant search which is highly error-prone (Ahuja & Lampert, 2001). A high level of market relatedness makes it less likely that entrepreneurs will engage in distant search thus lowering the variance of technology relatedness among these entrepreneurs. Further, at any given level of technology relatedness, a higher level of market knowledge will constrain the search function, diminishing the likelihood of undirected, broader search that could lead to the discovery of impactful new

knowledge. I posit that this constrained knowledge search at higher levels of market relatedness will lead to a lower likelihood of generating impactful inventions.

In sum, I argue that the curvilinear relationship between technology relatedness and later venture invention impact is moderated by the extent of market relatedness between the prior and later venture such that the rate of increase (or decrease) in invention impact will be higher at lower levels of market relatedness. This leads to my next hypothesis:

Hypothesis 3a: *Market relatedness moderates the curvilinear relationship between technology relatedness and the likelihood of later venture invention impact. Specifically, the rate of increase (decrease) in invention impact associated with decreasing (increasing) technology relatedness will be lower when market relatedness is higher.*

I argue that the positive effect of technology relatedness on later venture economic success is likely to be moderated by the extent of market relatedness between the prior and later ventures.

A high level of knowledge relatedness is likely to enable an entrepreneur to mitigate the risks involved in technology development for their new venture. An entrepreneur who starts his later venture in a similar technological context to their prior venture is likely to face the least difficulties in transferring knowledge effectively and engineering incremental knowledge recombinations (Ahuja & Lampert, 2001). Such a strategy is likely to increase the venture's ability to respond to new information correctly and improve its likelihood of successfully solving the technological challenges involved in product development (Katila & Ahuja, 2002). A higher level of market knowledge is likely to further strengthen this positive effect of technology relatedness on economic performance. A higher level of market relatedness is likely to lead the

entrepreneur to engage in focused technological problem solving as opposed to unlimited, undirected search. The entrepreneur's knowledge of the market is likely to improve his ability to anticipate and predict market trends and opportunities. In combination, having high levels of market and technological knowledge will significantly diminish a firm's risk of failure and improve its likelihood of achieving economic success. Indeed, as noted by Heiner (1986: p.84), a firm's ability to successfully operate is "a negative function [of distance] from an agent's immediate experience or from its local environmental situation".

Conversely, at low levels of technology relatedness, a firm faces elevated technology risk as the chances of finding a successful combination become more remote. Lower familiarity with technology components increases the difficulties involved in successful knowledge recombination and decreases the firm's likelihood of successfully solving its technological problems, thereby increasing its chances of failure (March, 1991). High entrepreneur market knowledge can mitigate this problem if it can enable the firm to achieve greater focus in its technology search. On the other hand, low market knowledge would compound this problem by increasing the risk of negative transfer and exacerbating the challenges arising from low technology relatedness. Thus I contend that ventures characterized by low technology and industry relatedness are likely to be characterized by very low likelihood of successful exits, potentially suffering from a 'failure trap' (Levitt and March, 1988).

This leads to my next hypothesis:

Hypothesis 3b: *Market relatedness moderates the positive relationship between technology relatedness and the likelihood of later venture successful exit such that high market*

relatedness strengthens the positive effect of technology relatedness on likelihood of later venture economic success.

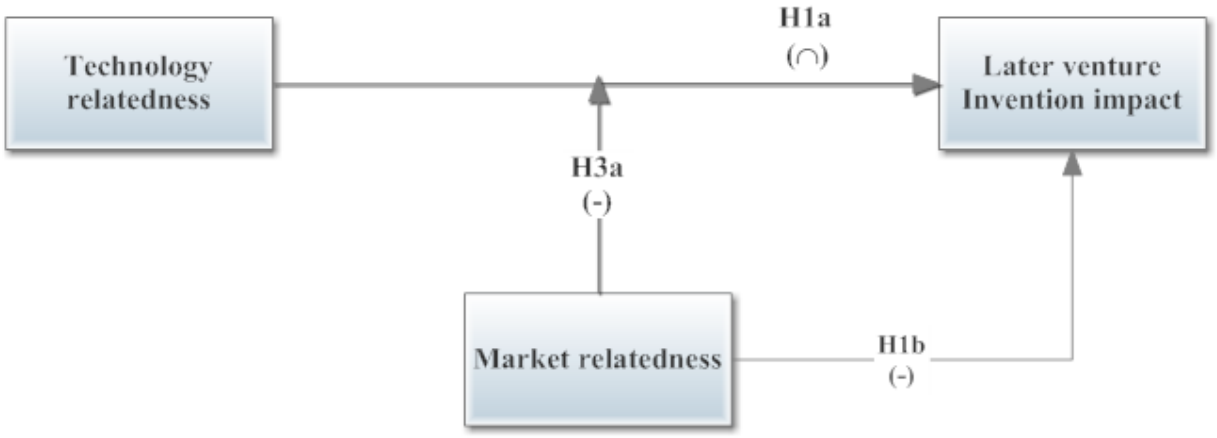

Figure 3-1: Conceptual Model predicting Invention Impact

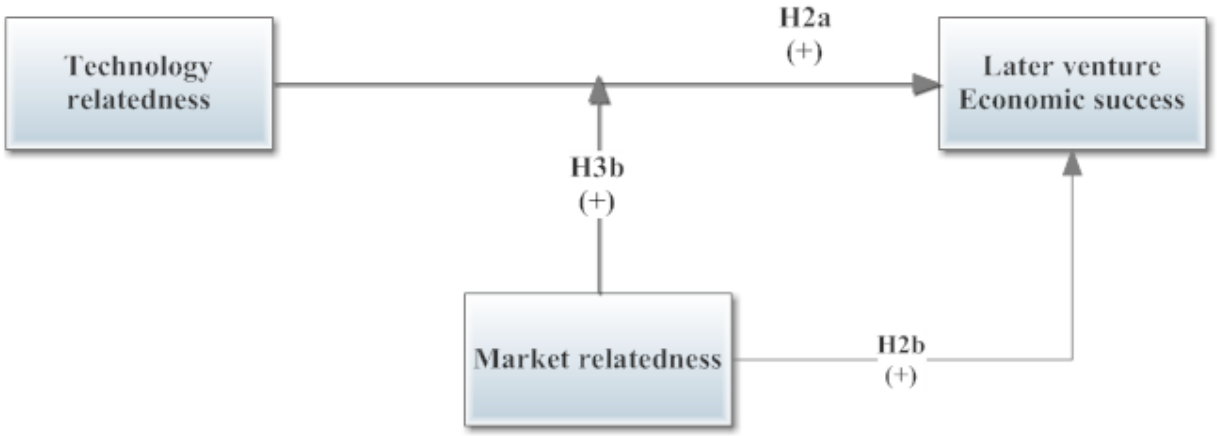

Figure 3-2: Conceptual Model predicting Economic Success

METHODS

Sample and Data Sources

Data used for conducting this study consists of venture capital (VC) funded ventures started by serial entrepreneurs in the period 1990 to 2005, spanning six knowledge-intensive industries: Biopharmaceuticals, Communications and Networking, Software , Medical Devices and Equipment, Semiconductors and Electronics and Computer Hardware. Data on company founders was obtained from the Dow Jones Venture Source database (previously called VentureOne). Venture Source was established in 1987 and includes data on all VC-funded entrepreneurial ventures since then, including detailed biographical information on founder and executive history. Numerous prior studies (e.g., Gompers et al., 2010) have used Venture Source and have attested to the quality of the data.

I obtained the sample by examining the information on company founders provided by Venture Source – this allowed me to identify a set of companies founded by serial entrepreneurs. I then identified all other companies started by this set of entrepreneurs and organized them by start date. In constructing this sample, I only considered firms where the entrepreneur founded firms one after another as opposed to taking a portfolio approach (Westhead, Ucbasaran, Wright, & Binks, 2005; Westhead & Wright, 1998). This process resulted in an initial sample of 718 venture-funded companies. I supplemented the founder data obtained from Venture Source with data on venture capital investments obtained from the ThompsonOne VentureXpert database. Previous studies (for example, Dimov & Milanov, 2010; Gulati & Higgins, 2003) have used this database as a reliable source for venture capital investment data. Data on company performance was triangulated across both Venture Source and VentureXpert databases. These firms were organized into 353 entrepreneur-company

dyads with the characteristics of the immediately previous venture started by a focal entrepreneur used to predict the performance of the subsequent venture.

Next, I removed 64 firm dyads from the sample because the outcome from the prior venture was not established prior to the founding of the later venture i.e. the entrepreneurs involved followed a portfolio approach. Hence these firms were outside the scope of this study. Being able to correctly identify the market focus of the firms was an important focus of this study. This was determined on the basis of 4-digit SIC code for the firms in my sample. However, for 24 firms in the sample, no information on the industry assignment was available. Hence these dyads were dropped from the analysis. Another important consideration was the ability to correctly determine the success or failure of the prior venture as this could significantly influence the choice of context for the later venture (Eggers & Song, 2015). This information was unavailable for 21 firms in my sample, which were dropped from the analysis. I also hand-collected the detailed career history of the entire founding team for the firms in my sample. This information was compiled from several sources including the firm's own websites, archives of the firm's websites (htttp://www.archive.org/), ZoomInfo, Business Week, LinkedIn etc. However, I was unable to gather this information for 18 firms in my sample; hence these firm dyads were excluded from the analysis. The resulting sample consisted of 441 firms organized into 226 venture-funded company-dyads. To these firms, I added patenting information using USPTO patent data obtained from Harvard Dataverse (Li et al., 2014). Out of these firms, 387 had a history of patenting that could be utilized to examine the technological trajectories of these firms. These firms, organized into 204 firm dyads, formed the final sample with which I began my analysis.

Measures

Dependent Variable

Invention Impact: I follow the established tradition in the literature of measuring invention impact through citation count of patents granted to the new venture (e.g. Ahuja & Morris Lampert, 2001; Arts & Veugelers, 2015; Conti et al., 2013). In order to ensure that the said patents represent the initial knowledge base of the venture as well as to allow a consistent cut-off for considering patent data across all the firms in my sample, I only consider patents applied for in the five-year period following the founding date of the venture. The 4 to 5 year cut-off window is considered an appropriate time period for assessing the knowledge base of a technology (Stuart and Podolny, 1996; Ahuja & Lampert, 2001).

The number of citations received by a patent is a measure of its technological importance (Albert, Avery, Narin, & McAllister, 1991) as well as its value to the firm (Harhoff et al., 1999). Most patents applications are ruled upon within two to three years of the application date. Hence, I excluded self-citations and considered citations received by the patent in the first five years following the application date of the patent. USPTO releases data on application date and grant date for all patents. I used this information to consider patent applications over the period 1990 through 2010 which correspond to the minimum and maximum possible years respectively for patent applications within the purview of my data, which has company start dates ranging from 1990 through 2005. I calculated the sum of all citations to patents filed by the new venture in the first five years following founding. Prior research has used similar measures to examine the impact of innovation by new ventures (Kortum & Lerner, 2000; Shan, Walker, & Kogut, 1994).

Economic success: The second dependent variable in this study is the performance of the later venture founded by the serial entrepreneur. Measuring performance of start-ups across industries using measures such as profit, revenue, and sales growth is inherently problematic as it risks ignoring fundamental differences across industries and ventures (Delmar & Shane, 2006). I use a binary classification scheme for classifying firms as successful or unsuccessful. A firm is considered to be successful if any of the following events occurred: (i) the firm went public or filed to go public by August 2012 (ii) the firm was acquired in a deal whose purchase price was greater than the total amount of capital raised by the firm. When the acquisition purchase price was undisclosed, I checked to see if any of the founders of the focal start-up joined the acquiring firm. If this was found to be true, then the firm was considered successful. A firm was classified as having failed if any of the following events occurred: (i) the firm filed for bankruptcy or had its assets sold, (ii) it was acquired in a deal where the purchase price was less than the total amount of capital raised by the firm, (iii) press reports indicated that the firm was in distress prior to the acquisition, and (iv) none of the founders of the focal start-up joined the acquiring firm. Using the above criteria, successful firms were coded as 1 and unsuccessful firms were coded as 0. A similar typology for classifying new venture outcomes as success or failure was followed by Arora and Nandkumar (2011) and Eesley, Hsu & Roberts (2014).

Independent Variables

Market relatedness: I use the inter-industry relatedness index developed by Bryce and Winter (2009) to assess the extent to which two successive ventures launched by a focal serial entrepreneur share known resource synergies. The use of this index overcomes the problem of failure to capture complementarities and synergies across seemingly unrelated industries that

are created in measuring relatedness solely based on matching digits across associated SIC codes. This index involves the generation of a relatedness score for an industry dyad by capturing the shortest path distance between the two industry nodes in the knowledge relatedness structure. The index harnesses relatedness information embedded in the multiproduct decision of diversified US firms, and is based on information on four-digit SIC codes of companies, to obtain the underlying knowledge structure associated with every pair of industries. The index is captured by the value of 'z' wherein a high value of 'z' indicates strong relatedness between two industries and low values of 'z' indicates low relatedness between two industries.

Technology relatedness: I calculate technology relatedness as the distance between the knowledge domains spanned by the entrepreneur's two successive ventures, as captured by their patent filings. This measure is constructed as the *Euclidean distance between patent classes* (Rosenkopf & Almeida, 2003). This measure is constructed by using the patent class information for each patent filed by the two ventures in the first five years since founding. Technology relatedness can then be calculated as:

$$(\sqrt{\sum_i (focal\ venture\ patent\ proportion - prior\ venture\ patent\ proportion)_i^2}$$

where, *i* is a distinct patent class and *patent proportion* refers to the proportion of patents in a specific patent class relative to all patents filed by the venture. The results were standardized to provide a continuous scale from 0 to 1. I then reverse-coded these values such that values close to 0 reflect low technology relatedness and values close to 1 reflect high technology relatedness across successive ventures founded by a focal entrepreneur.

Control Variables

I control for several other factors which can potentially drive the performance of the new venture. New venture performance outcomes are likely to be affected by the amount of resources at the disposal of the new venture (Kortum & Lerner, 2000). The use of venture capital data allows us to capture the role of such external resource providers in new venture outcomes. Accordingly, I include a control for amount of venture capital funding received (*funding amount*) by the new venture. The variable was logged in order to correct for skewness of its distribution.

The serial entrepreneur's background could influence the impact she has on the new venture. Thus, I include several variables that control for heterogeneity in the entrepreneur's previous background. I include a binary variable indicating whether the serial entrepreneur associated with the venture had a Ph.D. (*Ph.D.*), an MD (*MD*) or a Masters degree (*Masters*). Founders who are directly involved with invention activities may behave differently from founders who are not, in terms of their choices of later venture contexts. In addition, founders that engage in invention activities may initiate the start-up to commercialize their own inventions. To address these issues, I control for the entrepreneur's background as an inventor with a dummy variable (*Inventor*) that is set to 1 if the founder has any patents assigned to her name. To control for the serial entrepreneur's prior venture performance, I include a control variable for the number of prior ventures (*venture count*) and the performance of the immediate prior venture, *prior venture success.* This variable is coded in a way similar to the dependent variable 'Economic success', with the only difference being that the variable 'Prior venture success' is focused on performance of the venture founded earlier in time by a focal entrepreneur

and ‘Later venture success’ is focused on the performance of the venture founded chronologically later in time.

The *time elapsed* between founding of the two ventures is also potentially influential in determining learning and performance of the later venture. This is measured by obtaining the time difference across the start-dates of two successive ventures. This time elapsed between the founding of two successive ventures associated with the same serial entrepreneur is measured in years. I also control for the number of successfully granted patents that were filed by the firm in the first five years following its founding (*Firm patents*).

The entrepreneur’s *talent* has been recognized as an important driver of performance in entrepreneurial ventures (Eesley and Roberts, 2012). In order to measure ‘talent’, I take an approach similar to Eesley and Roberts (2012) and create a separate dataset organized as a panel of serial entrepreneurs and the founding year of the firm. I compute this measure by running a regression with individual entrepreneur-level fixed effects on the aggregate amount of venture capital funding obtained by the focal venture. The fixed effects thus obtained were then saved and utilized as a measure for talent in main regression model.

Other members of the founding team are also influential in the start-up. I include control variables for the team size, functional diversity and educational diversity of members of the founding team. Further, some companies may benefit disproportionately because of their location in an entrepreneurial hub like Silicon Valley in the state of California or Route 128 in the state of Massachusetts. Accordingly, I include *State* dummy variables ‘CA’ and ‘MA’ indicating whether the focal firm was located in California or in the state of Massachusetts.

Having a high status venture capitalist may significantly improve a venture's prospects as such investors are known to provide new ventures with "extra-financial" value by way of their participation in the firm's activities and governance which can significantly improve the new venture's future prospects (Hsu, 2004). Following prior research (Hochberg, Ljungqvist, & Lu, 2007; Lee, Pollock, & Jin, 2011; Petkova, Wadhwa, Yao, & Jain, 2014), I operationalize *VC status* as eigenvector centrality (Bonacich, 1987)) which captures every VC's direct co-investment connections in a given time period and then recursively weighs each connection by the connected VCs' centrality. This measure followed Lee et al. (2011). I also include a dummy variable (*VC Repeat*) that is set to 1 if the entrepreneur receives funding from the same venture capitalist across both focal ventures. Finally, given that my data spans six industries and multiple founding years, I incorporate dummy variables to account for heterogeneity at the industry level and founding year level.

Addressing Endogeneity Concerns

Concerns about endogeneity have to be taken into account as unobserved heterogeneity may simultaneously drive an entrepreneur's choices for the later venture as well as firm performance. To address this issue, I undertake a matching approach through coarsened exact matching (CEM) (Blackwell, Iacus, King, & Porro, 2009) to match ventures whose founders had failed versus those whose founders had succeeded in the prior venture. The literature on matching suggests that the use of appropriately stringent matching mitigates concerns about endogeneity and minimizes sensitivity of regression results to specific functional form assumptions. Following prior research (Hsu, 2006; Pahnke et al., 2015a), I use industry, geography and founding year as matching criteria. Implementing matching limited my sample to 175 firm-dyads consisting of 334 firms.

Model Specification and Estimation

I used two statistical analysis methods to test my hypotheses. My first dependent variable, invention impact is derived from patent citation data and takes on only non-negative values and is a count variable. Poisson regression can be used to analyze such data, but the negative binomial regression model is preferred when the assumption of the equality of the conditional mean and variance functions is violated (Greene, 2003). Since a likelihood ratio test indicated overdispersion, I used the negative binomial regression for the analysis of these data. The negative binomial model handles the issue of overdispersion by introducing an individual unobserved disturbance term that allows the conditional mean and variance to vary.

My second dependent variable, new venture success, is binary in nature. Such limited dependent variables violate key assumptions underlying linear regression models such as the presence of homoskedastic, normally distributed error terms. To address these problems I use logistic regression for the analytical framework.

RESULTS

Table 3-2 provides the pairwise correlation matrix and descriptive statistics of the variables in the study. An inspection of the correlations does not reveal any multicollinearity concerns. Table 3-3 presents the results of the negative binomial regression used to examine the invention impact of the later venture. In Table 3-3, Model 1 is the baseline model with only control variables. Model 2 introduces the linear measure of Technology Relatedness and Model 3 introduces its squared term. Model 4 introduces the direct effect of market relatedness. Model 5 introduces the interaction between technology and market relatedness. A similar convention is followed in the case of Table 3-4 that presents the results of the logistic regression used to

examine the likelihood of economic success of the later venture launched by the serial entrepreneur.

Table 3-3, Model 1 presents the regression results with all control variables incorporated. The results show that founders with advanced educational qualifications such as an MD, a Ph.D. or a Masters in a technical field are more likely to found more innovative firms. The total amount of funding received by the firm is also predictive of innovation impact, as is, perhaps unsurprisingly, the number of firm patents in its first five years. Models 2, 3 and 4 test the main effects predicting invention impact without the addition of any interaction terms. For a conservative test of the study's hypotheses, I evaluated all results using two-tailed t-tests and robust standard errors.

Table 3-2: Correlation Table

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
Patent Citations	0.52	0.5	1																		
Tech. Relatedness	0.59	0.19	0.21	1																	
Market Relatedness	1.23	1.58	0.16	0.18	1																
Time elapsed	4.13	2.78	0.05	-0.15	0.14	1															
Funding (logged)	3.55	1.24	0.21	0.22	-0.03	0.01	1														
Inventor	0.7	0.46	0.08	0.2	0.15	0.07	-0.09	1													
MD	0.09	0.29	0.08	0.05	0.06	0.07	0.08	0.21	1												
Ph.D.	0.42	0.5	0.03	0.11	-0.05	-0.2	0.09	0.27	0.03	1											
Masters	0.3	0.46	-0.05	0.04	0.01	0.06	0.03	-0.1	-0.09	-0.51	1										
Talent	1.71	2.71	0.11	0	-0.1	-0.12	-0.04	0.02	0.02	0.08	-0.09	1									
CA	0.63	0.48	0.06	-0.03	-0.01	0.14	0.01	-0.05	0.01	0	0.1	-0.11	1								
MA	0.17	0.37	0.07	-0.09	0.01	0.01	0.1	0.07	0.01	0.04	0	0.02	-0.59	1							
Venture Count	2.04	1.81	0.03	0.02	-0.13	-0.12	0.05	-0.09	-0.06	0.04	-0.08	0.01	0.03	0.08	1						
Prior Success	0.59	0.49	0.06	0	0.12	0.17	0.04	0.09	0.12	-0.04	-0.04	-0.07	-0.07	0.22	0.01	1					
Number of founders	2.51	1.28	0.07	-0.08	-0.1	-0.02	0.1	-0.06	-0.05	0.08	0.04	-0.03	-0.12	0.29	0.18	0.07	1				
Team diversity (edu. spez.)	0.45	0.26	0.1	0.05	0.03	0.08	0.06	0.02	0.02	-0.11	0.02	0.12	-0.05	-0.04	0.02	0.17	0.07	1			
Team Diversity (edu. level)	0.31	0.23	0.03	-0.03	-0.08	-0.01	-0.04	0.11	-0.03	0.02	0.11	-0.02	0.03	0.07	0.07	-0.02	-0.05	-0.08	1		
Firm Patent count	14.72	18.65	0.2	0.17	-0.03	-0.03	0.22	-0.02	0.02	0.08	-0.09	0.1	0.08	-0.14	0.12	-0.08	-0.17	0.11	0.06	1	
VC Status	0.17	0.17	0.01	-0.06	-0.11	0.07	0.34	-0.09	0.12	0.06	0.03	0	0.15	-0.15	-0.05	-0.12	-0.02	-0.03	-0.01	0.16	1
VC repeat	0.36	0.48	-0.02	0.08	0.07	-0.08	0.12	0.03	0.11	-0.04	-0.02	0.07	0.05	0.1	0.18	0.01	0.22	0.04	0.07	-0.05	0.15

Correlations equal to or greater than .20 are significant at the .05 level.

Table 3-3: Analysis of Invention Impact of ventures founded by serial entrepreneurs

	Model 1	Model 2	Model 3	Model 4	Model 5
Technology relatedness – **H1a**		2.057*	12.718***	13.424***	9.977*
		(0.927)	(3.616)	(3.613)	(4.494)
Technology relatedness squared – **H1a**			-9.347**	-9.516**	-7.244+
			(3.192)	(3.153)	(4.031)
Market relatedness – **H1b**				-0.234**	-2.386**
				(0.083)	(0.795)
Technology relatedness * Market relatedness – **H3a**					6.430*
					(2.629)
Technology relatedness squared * Market relatedness – **H3a**					-4.465*
					(2.087)
Time elapsed	-0.082	-0.084+	-0.104*	-0.087+	-0.098*
	(0.050)	(0.049)	(0.049)	(0.049)	(0.044)
Total funding (logged)	0.310**	0.177	0.225+	0.176	0.212
	(0.120)	(0.134)	(0.131)	(0.137)	(0.139)
MD	1.091*	1.030*	1.090*	1.251**	1.300**
	(0.474)	(0.454)	(0.459)	(0.447)	(0.491)
Ph.D.	0.604*	0.504+	0.566*	0.510+	0.535+
	(0.266)	(0.276)	(0.280)	(0.267)	(0.282)
Masters	0.834**	0.787**	0.839**	0.796**	0.756*
	(0.295)	(0.301)	(0.307)	(0.305)	(0.300)
Inventor	0.249	0.069	0.228	0.340	0.303
	(0.317)	(0.316)	(0.321)	(0.315)	(0.301)
Talent	0.021	0.016	0.015	0.021	0.026
	(0.044)	(0.044)	(0.044)	(0.043)	(0.043)
Prior venture count	0.093	0.129	0.113	0.105	0.081
	(0.111)	(0.117)	(0.116)	(0.113)	(0.112)
Prior venture success	0.240	0.201	0.067	0.070	0.070
	(0.264)	(0.264)	(0.267)	(0.254)	(0.247)
Number of founders	-0.100	-0.040	-0.116	-0.119	-0.159
	(0.121)	(0.129)	(0.131)	(0.126)	(0.130)
Team diversity (educational specialization)	0.299	0.489	0.342	0.532	0.309
	(0.587)	(0.601)	(0.620)	(0.610)	(0.613)
Team diversity (educational level)	-0.522	-0.521	-0.723	-0.890	-0.958
	(0.736)	(0.729)	(0.748)	(0.690)	(0.678)
Firm patents	0.077***	0.075***	0.070***	0.070***	0.071***
	(0.015)	(0.014)	(0.013)	(0.013)	(0.013)
VC Status	-1.757	-1.097	-1.125	-1.180	-1.619
	(1.238)	(1.335)	(1.281)	(1.234)	(1.249)
VC Repeat	0.331	0.179	0.217	0.142	0.262
	(0.290)	(0.308)	(0.308)	(0.308)	(0.299)
	(0.471)	(0.476)	(0.470)	(0.459)	(0.456)
Constant	0.386	-0.509	-3.001**	-3.112**	-1.631
	(0.788)	(0.944)	(1.075)	(1.130)	(1.364)
Location dummies	Yes	Yes	Yes	Yes	Yes
Founding Year dummies	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes

Number of observations	175	175	175	175	175
Log likelihood	-738.3	-736.3	-733.2	-730.5	-728.1
Chi2	1000	1045	882.3	928.8	1135

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ()

Table 3-4: Analysis of Economic Success of ventures founded by serial entrepreneurs

	Model 1	Model 2	Model 3	Model 4
Technology relatedness – **H2a**		2.421*	1.991	1.977
		(1.188)	(1.262)	(1.570)
Market relatedness – **H2b**			0.400*	0.392
			(0.177)	(0.439)
Technology relatedness * Market relatedness – **H3b**				0.013
				(0.684)
Time elapsed	0.001	0.017	-0.030	-0.030
	(0.073)	(0.075)	(0.080)	(0.080)
Total funding	0.508**	0.415*	0.472*	0.472*
	(0.193)	(0.195)	(0.218)	(0.218)
MD	0.189	0.123	0.046	0.046
	(0.693)	(0.688)	(0.675)	(0.675)
Ph.D.	-0.498	-0.655	-0.643	-0.644
	(0.462)	(0.474)	(0.497)	(0.503)
Masters	-0.539	-0.664	-0.656	-0.656
	(0.492)	(0.492)	(0.506)	(0.512)
Inventor	0.445	0.202	0.106	0.106
	(0.440)	(0.461)	(0.478)	(0.478)
Talent	0.196*	0.202*	0.237**	0.237*
	(0.081)	(0.081)	(0.091)	(0.092)
Prior venture count	0.041	0.065	0.121	0.121
	(0.126)	(0.136)	(0.135)	(0.134)
Prior venture success	0.235	0.252	0.310	0.310
	(0.399)	(0.391)	(0.409)	(0.409)
Number of founders	0.239	0.286	0.370+	0.370+
	(0.188)	(0.196)	(0.214)	(0.214)
Team diversity (educational specialization)	0.167	0.130	0.113	0.112
	(0.714)	(0.700)	(0.695)	(0.692)
Team diversity (educational level)	0.704	0.850	1.097	1.096
	(0.912)	(0.932)	(0.971)	(0.974)
Firm patents	0.023+	0.020+	0.022+	0.022+
	(0.012)	(0.012)	(0.011)	(0.011)
VC status	-1.499	-1.041	-0.662	-0.659
	(1.404)	(1.436)	(1.450)	(1.451)
VC repeat	-0.925*	-1.110*	-1.452**	-1.453**
	(0.464)	(0.470)	(0.546)	(0.546)
Constant	-1.948	-3.294	-3.838+	-3.830
	(1.805)	(2.054)	(2.284)	(2.392)
Location dummies	Yes	Yes	Yes	Yes
Founding Year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Number of observations	175	175	175	175
Log likelihood	-99.05	-96.71	-92.60	-92.60
Chi2	34.81	38.33	34.69	34.71

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ()

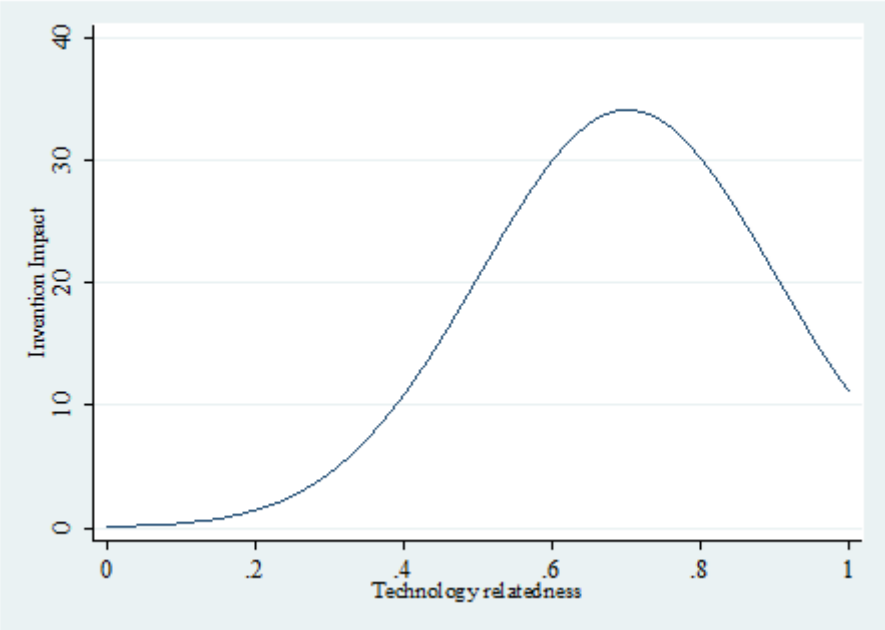

Figure 3-3: Relationship between Technology relatedness and Invention Impact

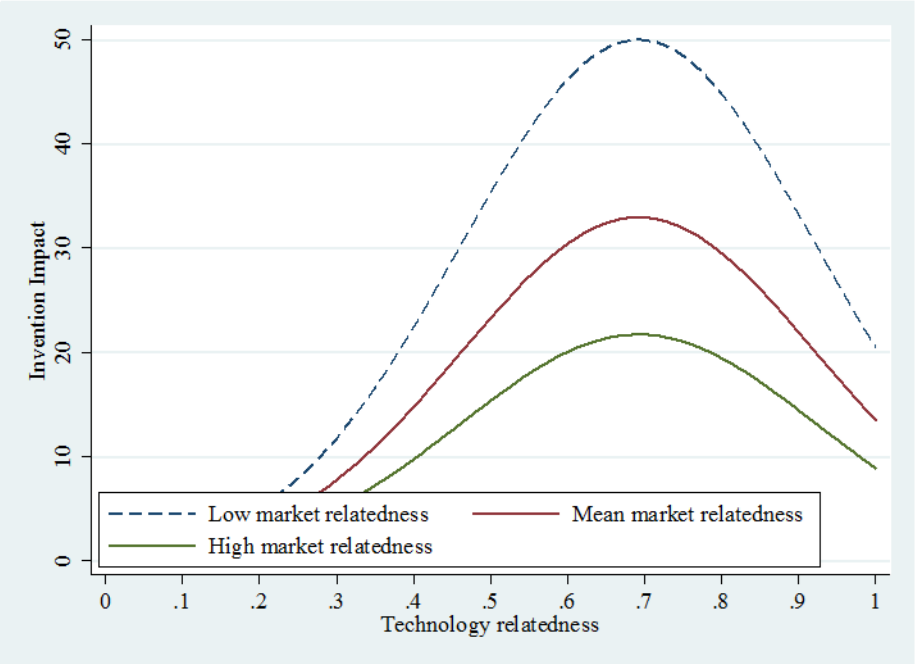

Figure 3-4: Interactive effect of Technology relatedness and Market relatedness on Invention Impact

Table 3-5: Additional analysis – Testing whether market relatedness mediates the relationship between technology relatedness and economic success

Dependent variable	**Model 1** Later venture economic success	**Model 2** Market relatedness	**Model 3** Later venture economic success	**Model 4** Later venture economic success
Technology relatedness	2.421*	1.372*		1.991
	(1.188)	(0.653)		(1.262)
Market relatedness			0.428*	0.400*
			(0.169)	(0.177)
Time elapsed	0.017		-0.045	-0.030
	(0.075)		(0.078)	(0.080)
Total funding	0.415*	0.034	0.548**	0.472*
	(0.195)	(0.119)	(0.207)	(0.218)
MD	0.123	0.277	0.099	0.046
	(0.688)	(0.502)	(0.682)	(0.675)
Ph.D.	-0.655	-0.407	-0.523	-0.643
	(0.474)	(0.338)	(0.487)	(0.497)
Masters	-0.664	-0.159	-0.583	-0.656
	(0.492)	(0.334)	(0.520)	(0.506)
Inventor	0.202	0.433	0.294	0.106
	(0.461)	(0.295)	(0.466)	(0.478)
Talent	0.202*	-0.040	0.231**	0.237**
	(0.081)	(0.045)	(0.089)	(0.091)
Prior venture count	0.065	-0.096+	0.099	0.121
	(0.136)	(0.054)	(0.124)	(0.135)
Prior venture success	0.252	0.103	0.274	0.310
	(0.391)	(0.263)	(0.418)	(0.409)
Number of founders	0.286	-0.111	0.332	0.370+
	(0.196)	(0.118)	(0.205)	(0.214)
Team diversity (educational specialization)	0.130	-0.157	0.183	0.113
	(0.700)	(0.465)	(0.708)	(0.695)
Team diversity (educational level)	0.850	-0.643	1.009	1.097
	(0.932)	(0.595)	(0.974)	(0.971)
Firm patents	0.020+		0.024*	0.022+
	(0.012)		(0.011)	(0.011)
VC status	-1.041	-0.918	-0.961	-0.662
	(1.436)	(0.866)	(1.417)	(1.450)
VC repeat	-1.110*	0.339	-1.324*	-1.452**
	(0.470)	(0.313)	(0.525)	(0.546)
Constant	-3.294	1.293	-2.828	-3.838+
	(2.054)	(0.902)	(2.075)	(2.284)
Location dummies	Yes	Yes	Yes	Yes
Founding year dummies	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes
Number of observations	175	175	175	175

Log likelihood	-96.71		-94.07	-92.60
Chi2	38.33		31.55	34.69
R-Squared		.2309		

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ().
Models 1, 3 and 4 were specified using logistic regression. Model 2 was specified using OLS regression.

Table 3-6: Robustness checks

Dependent Variable	**Model 1** Invention Impact	**Model 2** Invention Impact	**Model 3** Economic Success	**Model 4** Invention Impact	**Model 5** Invention Impact	**Model 6** Economic Success
Technology relatedness	10.475**	8.654+	1.528	14.702**	7.939	1.215
	(3.551)	(4.837)	(1.152)	(5.313)	(6.078)	(1.460)
Technology relatedness squared	-7.090*	-6.250		-10.905*	-5.834	
	(3.101)	(4.346)		(4.622)	(5.406)	
Market relatedness	-0.300***	-2.037*	0.299*	-0.187+	-2.801*	0.371*
	(0.075)	(0.816)	(0.149)	(0.112)	(1.211)	(0.189)
Technology relatedness * Market relatedness		4.931+			8.524*	
		(2.661)			(3.966)	
Technology relatedness squared * Market relatedness		-3.240			-6.317*	
		(2.087)			(3.000)	
Time elapsed	-0.013	-0.028	0.015	-0.228***	-0.258***	0.192+
	(0.051)	(0.049)	(0.075)	(0.067)	(0.065)	(0.102)
Total funding	0.165	0.193	0.443*	0.133	0.119	0.197
	(0.133)	(0.137)	(0.208)	(0.229)	(0.219)	(0.251)
MD	0.780*	0.847*	-0.230	0.625	0.203	-1.163
	(0.388)	(0.397)	(0.622)	(0.714)	(0.753)	(0.947)
Ph.D.	0.232	0.228	-0.057	0.934*	0.933+	-0.406
	(0.259)	(0.256)	(0.447)	(0.459)	(0.477)	(0.681)
Masters	0.679*	0.661*	-0.225	0.670	0.659	-0.138
	(0.292)	(0.288)	(0.475)	(0.473)	(0.447)	(0.665)
Inventor	0.485+	0.481+	0.096	0.440	0.416	0.900
	(0.283)	(0.275)	(0.401)	(0.489)	(0.476)	(0.615)
Talent	0.043	0.051	0.134+	-0.051	-0.016	0.259*
	(0.042)	(0.041)	(0.077)	(0.071)	(0.080)	(0.101)
Prior venture count	0.049	0.031	-0.051			
	(0.069)	(0.068)	(0.099)			
Prior venture success	0.102	0.118	0.084	0.305	0.416	-0.038
	(0.237)	(0.236)	(0.364)	(0.361)	(0.355)	(0.511)
Number of founders	-0.156	-0.176	0.213	-0.031	-0.160	0.119
	(0.119)	(0.118)	(0.176)	(0.183)	(0.203)	(0.256)
Team diversity (Educational specialization)	0.553	0.369	0.046	0.152	-0.095	-0.566
	(0.507)	(0.515)	(0.644)	(0.821)	(0.837)	(0.930)
Team diversity (Educational level)	-0.632	-0.740	0.993	0.035	-0.023	0.978
	(0.613)	(0.622)	(0.834)	(0.897)	(0.868)	(1.021)
Firm Patents	0.071***	0.072***	0.015	0.064**	0.061**	0.003
	(0.016)	(0.016)	(0.011)	(0.020)	(0.019)	(0.010)
VC Status	-0.880	-1.209	0.267	0.654	0.383	0.675
	(1.050)	(1.062)	(1.355)	(1.570)	(1.585)	(1.505)
VC Repeat	0.132	0.175	-0.734+	-0.034	0.161	-0.280
	(0.268)	(0.259)	(0.435)	(0.394)	(0.409)	(0.606)
Constant	0.168	0.838	-2.858	-2.595	0.050	-3.772*
	(1.365)	(1.624)	(1.952)	(1.597)	(2.069)	(1.536)

Location dummies	Yes	Yes	Yes	Yes	Yes	Yes
Founding year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	204	204	204	94	94	94

Notes: *** p<0.001, ** p<0.01, * p<0.05, + p<0.1, two-tailed t-tests, Robust standard errors in parentheses ().
Models 1, 2 and 3 were implemented using the full sample of 204 firm-dyads with no matching implemented.
Models 4, 5 and 6 were implemented for firms where the serial entrepreneur had only 1 prior venture – 94 firm dyads.

Hypothesis 1 predicted that technology relatedness should have a curvilinear relationship with later venture invention impact. In Model 2 (Table 3-3), I first include only the linear term predicting technology relatedness. The resulting coefficient is positive and significant (Model 2; $\beta = 2.05$; $p < .05$). To test whether this relationship is, in fact, non-linear, I add squared term for technology relatedness in Model 3. In this model, the coefficient of the linear term for technology relatedness remains positive and strongly significant (Model 3; $\beta = 12.71$; $p < .001$) while the squared term is negative and significant (Model 3; $\beta = -9.34$; $p < .01$). Thus the results of Model 3 support H1a. Figure 3-3 is a graphical representation of the relationship between technology relatedness and new venture invention impact. Interestingly, the results show an optimal technology relatedness of approximately 0.7, suggesting that a mix of familiar and unfamiliar technologies (but more familiar than unfamiliar) are most optimal for developing impactful inventions. Hypothesis 1b proposed that market relatedness across successive ventures started by a serial entrepreneur is negatively associated with later venture invention impact. I test this hypothesis in Model 4. Consistent with Hypothesis 1b, the coefficient of market relatedness is negative and significant (Model 4, $\beta = -0.234$, $p<.01$), providing evidence that higher levels of market relatedness can negatively impact invention impact.

Model 5 (Table 3-3) tests the interactive effect of market and technology relatedness on invention impact. In non-linear regression models, the evaluation and interpretation of the marginal effects of an interaction term depends on the values of all the variables in the model (Long and Freese, 2006). Interpretation of these models can be done by holding other regressors in the model at their mean values (Cameron & Trivedi, 2010). The first interaction term is positive and significant (Model 5, $\beta = 6.43$, $p < .05$), and the second is negative and

significant (Model 5, $\beta = -4.46$, $p < .05$). Figure 3-4 provides a graphical representation of this relationship which plots the effect of technology relatedness on invention impact at 3 levels of market relatedness: at its mean, at one standard deviation above the mean and at one standard deviation below the mean. An examination of Figure 3-4 clearly suggests that higher market relatedness is associated with higher levels of technology relatedness suggesting that entrepreneurs who have higher market knowledge are also more likely to have a more focused technology search strategy. In addition, we see that although the optimal level of invention impact occurs at approximately the 0.7 mark for all three curves, the impact is much higher for firms with lower market relatedness. Thus suggests that even at the same level of technology relatedness, greater market knowledge attenuates the invention impact of firms. Further, I note that the slopes of the curves modeling lower levels of market relatedness are sharper and more pronounced and associated with higher levels of invention impact. Taken together, these observations are in line with my expectations in Hypothesis 3a. Hence Hypothesis 3a is supported.

Table 3-4, Model 1 presents the results for the regression of the control variables on the likelihood of the later venture's economic success demonstrated through a successful exit. As may be expected, the size of funding received from venture capitalists is strongly predictive of economic success. I also note the significance of the talent variable suggesting that an entrepreneur's innate ability may have a significant influence on the likelihood of a venture's achieving economic success (Eesley et al., 2012, Gompers et al., 2010). Models 2 and 3 incorporate the direct effect of the two independent variables – technology relatedness and market relatedness respectively. Model 2 confirms that technology relatedness has a positive effect on the likelihood of later venture economic success (Model 2, $\beta = 2.42$, $p <$

.05). Similarly, Model 3 confirms that market relatedness has a positive effect on the likelihood of later venture economic success (Model 3, $\beta = .4$, $p < .05$). However, I note that the addition of the measure of market relatedness weakens the coefficient for technology relatedness and renders it insignificant (Model 3, $\beta = 1.99$, $p > .1$). This may be indicative of a mediation relationship which I investigate separately. In Model 4, I test for the interactive effect of technology and market relatedness on the likelihood of later venture economic success. However, I do not find support for this interactive effect, which was predicted by Hypothesis 3b. Hence this hypothesis is not supported (Model 4, $\beta = .01$, $p > .1$).

Additional Analysis: Testing for mediation

While testing for the relationship between market relatedness and firm economic success, I noticed that the previously significant coefficient of technology relatedness was weakened and rendered insignificant. Since this may be indicative of suppression due to a mediation relationship, I follow the steps in Baron and Kenny (1986) to formally test for the existence of a mediation relationship where market relatedness mediates the relationship between technology relatedness and firm economic success. These tests are tabulated in Table 3-5.

In the first step, I test for the existence of a direct relationship between technology relatedness and later venture economic success in Model 1. As expected, the coefficient is positive and significant (Model 1, $\beta = 2.42$, $p < .05$). I then test to see whether technology relatedness can predict market relatedness. This relationship is tested through an OLS regression model in Model 2. The coefficient of technology relatedness is positive and strongly significant (Model 2, $\beta = 1.37$, $p < .05$). Next, I test for the existence of a direct relationship between market relatedness and later venture economic success in Model 3. The coefficient of market relatedness is positive and significant which is in line with my

hypothesized expectations (Model 3, $\beta = 0.42$, $p < .05$). Finally, when I include, both technology relatedness and market relatedness in the model predicting later venture economic success, as previously noted, the coefficient of technology relatedness is weakened and insignificant (Model 4, $\beta = 1.99$, $p > .1$), while that of market relatedness remains positive and significant (Model 2, $\beta = 0.5$, $p < .05$). These tests indicate that market relatedness mediates the relationship between technology relatedness and later venture economic success. On the basis of this evidence, I include below the revised model predicting firm economic success.

Figure 3-5: Empirical Model predicting Economic Success

Robustness Checks

Because of the presence of interactions in the regression models, multicollinearity is a potential concern. This can be tested by examining the variance inflation factor (VIF) for the full model. The VIF values give an indication of the correlation of each variable with other regressors included in the model that could potentially inflate the variance of the estimated coefficient for that variable. Typically, VIF values less than 10 indicate that multicollinearity is not a concern in the regression model (Kennedy, 2008). The mean variance inflation factor (VIF) is 1.31 and the maximum VIF value is 1.92, suggesting that multicollinearity is not a serious problem in the analysis.

I also include the results of running the analysis on the entire sample of 204 firm-dyads with no matching implemented (Table 3-6, Models 1, 2 and 3). In order to address the

possibility that my results are confounded by the number of prior ventures started by the entrepreneur, I test the hypotheses on the subset of firms whose founders had only one prior founding experience. This limited the sample to 94 firm dyads (Table 3-6, Models 4, 5 and 6). The results for these tests were consistent with my previously reported analysis.

DISCUSSION

In this study, I sought to investigate how heterogeneity in two key contexts relevant to technology entrepreneurship – choice of technology and market, impact venture performance. I draw on insights from the literatures on learning, innovation and entrepreneurship and combine them to obtain a more nuanced understanding of the conditions under which prior founding experience can lead to superior performance of ventures founded by serial entrepreneurs. By focusing on serial entrepreneurs and examining the extent of technology and market relatedness across successive venture contexts and its impact on venture performance, this study shows that founders' choice of key venture contexts can have differential and competing implications for the venture's performance. Specifically, I find that technology relatedness has a curvilinear effect on invention impact and has a positive influence on the likelihood of the venture's economic success. Market relatedness, however, is associated with lower invention impact but higher likelihood of economic success, demonstrated by a successful exit. I also find that market relatedness moderates the effect of technology relatedness on invention impact such that the rate of increase (or decrease) in invention impact will be higher at lower levels of market relatedness. In subsequent analysis, I also found that the relationship between technology relatedness and firm economic success is mediated by market relatedness. I discuss the implications of these results for theory and practice next.

First, studies in the learning literature examining the implications of prior experience have typically either focused attention on its learning implications (e.g. Gompers et al., 2010; Toft-Kehler et al., 2014) or on the derived resource benefits (e.g. Hsu, 2007; Shane & Cable, 2002; Shane & Stuart, 2002). This study contributes to this literature by combining these perspectives to understand how contingencies shape the extent and nature by which prior experience translates into subsequent performance and furthers the research agenda by offering a more nuanced understanding of when and how heterogeneity in learning contexts impacts subsequent performance (Argote & Miron-Spektor, 2011) in entrepreneurship (Corbett, 2007; Holcomb et al., 2009; Krueger, 2007). Though much has been written in extant management and entrepreneurship literature about the importance of learning from prior experience, my findings suggest that prior entrepreneurial experience in and of itself is insufficient. Instead, taking a contingent perspective may be a much more effective approach towards understanding and analyzing the implications of such experience on subsequent performance. I show that choice of technology and market in new ventures pursued by a serial entrepreneur, and their relationship to the entrepreneur's past ventures, play a critical role in determining the performance of the new venture. This finding is consistent with prior work suggesting that experiential learning is typically context-specific (Bingham and Eisenhardt, 2011; March, 2011).

Second, this research addresses calls by scholars (e.g. Katila & Shane, 2005) to examine whether contexts that support innovation might differ from those that support firm financial success. Knowledge gained through prior entrepreneurial experience shapes entrepreneurs' behavior and perceptions in important ways. This study thus makes an important contribution to the literature on entrepreneurial learning by identifying important

trade-offs that arise due to the myopic nature of this learning. Thus I propose that subsequent research should pay greater attention to the relationship between different types of founder knowledge and different indicators of firm performance

Third, my findings also contribute to the literature on founder pre-entry knowledge (Burton & Beckman, 2007; Dencker & Gruber, 2014; Fern, Cardinal, & O'Neill, 2012) by shedding light on the relationships between two important types of founder pre-entry knowledge - technological knowledge and market knowledge, and explicating their impact on two important indicators of firm performance. While existing studies have identified market and technological knowledge as important determinants of venture performance outcomes, they have not considered the ways in which these types of knowledge can shape different dimensions of entrepreneurial performance in competing ways. My research thus deepens insights from existing research (Lazear, 2005) that suggests that the relative value of founder prior knowledge on entrepreneurial outcomes depends on contextual factors. In addition, my finding that market relatedness mediates the relationship between technology relatedness and firm economic success complements existing research (Gruber et al., 2013b) that shows that the value of founders' technological knowledge is contingent on their market specific knowhow, while also extending it by showing that the nature of this relationship is different, depending upon the outcome under consideration.

Fourth, this study addresses calls by scholars (e.g. Eggers & Song, 2015; Ucbasaran, Westhead, & Wright, 2008) for greater research focusing on the role of the individual in serial entrepreneurship. My findings contribute to the literature on serial entrepreneurship by drawing attention to the fundamental trade-offs that serial entrepreneurs face when they pick key contexts for their subsequent ventures and continues to support the notion that learning in

the entrepreneurial context is not a simple or linear process (Hsu, 2007; Eggers & Song, 2015; Eesley & Roberts, 2012; Toft-Kehler et al., 2014). In particular, while prior studies have primarily focused on the positive impact of accumulation of market knowledge on firm performance, this study extends this literature by showing that extensive knowledge endowments can impact performance in both positive as well as negative ways.

The results of this study also have important implications for practicing serial entrepreneurs. My results suggest that because future entrepreneurial decisions and actions are significantly influenced by the entrepreneurs' previous founding experiences, serial entrepreneurs need to be more mindful of their cognitive biases and contingent search trajectories which can have a substantial impact on the success of their subsequent ventures.

Limitations and directions for further research

An important limitation of this study is my reliance on data on VC funded serial entrepreneurs for sourcing my sample. Constraining the study to VC-funded firms imposes limits on the generalizability of the study. Firms that obtain VC funding are usually high potential firms in high growth industries and thus cross a higher threshold for quality and potential for growth and survival than many firms which do not receive VC funding. However, despite this limitation, examining VC-funded firms to study this question also provides significant benefits in the context of this study. First, the longitudinal nature of my research question which called for the ability to track a sample of serials entrepreneurs across multiple ventures necessitated longitudinal multi-industry data. The only data that met such requirements and was accessible was that of VC-funded entrepreneurial firms. Second, the use of VC-data allows me to track fairly robust performance data, which would be difficult to ascertain otherwise. Third, because this study is focused on young companies in the high-tech

sector, a natural focus for the venture capital industry, the setting allows me to have a certain level of homogeneity in the quality of human capital that the entrepreneurs possess. Nevertheless, future research that examines whether the results would be different if all ventures (both VC-funded as well non-VC-funded) started by entrepreneurs are considered, could be fruitful.

In keeping with my research question, I have limited myself to evaluating a broad definition of success that simplifies much of the inherent performance variation among firms. While the multi-industry nature of my context has several advantages, one of its disadvantages is that it renders inter-industry comparisons of firm performance very challenging. As a result, for my analysis, I have followed prior research (e.g. Arora and Nandkumar, 2011; Gompers et al., 2010) in adopting a binary dependent variable to capture economic success and the count of citations to patents to capture innovation success. However, future research should investigate the influence of prior founding experiences on other outcomes such as long term firm survival and alternate measures of innovation success.

An important finding of this research is the suggestion that experienced entrepreneurs who operate in contexts unrelated to their prior experiences may exhibit some characteristics similar to inexperienced entrepreneurs (Baron & Ensley, 2006) such as greater openness to explore and innovate. While, due to data limitations, I am unable to examine the comparative effectiveness of experienced and inexperienced entrepreneurs in terms of their success in innovation generation, this is an important avenue for research that should be pursued in future studies.

Another possible direction for future studies can be an examination of the specific nature of learning (e.g. opportunity recognition etc.) that is gleaned from experience by serial

entrepreneurs. It may also be fruitful to examine how prior entrepreneurial experience impacts the risk appetite of entrepreneurs and extending the insights provided by existing research (e.g. Dencker and Gruber, 2014) on what types of knowledge improve founders' ability to manage greater risk.

Conclusion

Though the importance of technology and market knowledge for venture performance has been well recognized in the literature, earlier investigations of entrepreneurial firms have ignored key trade-offs involved in important indicators of firm performance. By considering and integrating recent findings on the effects of prior entrepreneurial experience, my study helps to develop a more in-depth understanding of experiential learning in entrepreneurship for both theory and practice. My work is a first step in unpacking and resolving the extant conflicting empirical evidence on the implications of prior performance in entrepreneurship on later venture performance. I hope that these findings will stimulate further investigation of this research question and bring greater clarity to the problem of identifying conditions under which prior entrepreneurial experience acts as a good teacher and when it does not.

CONCLUSION AND FINAL THOUGHTS

The objective of this dissertation was to advance our understanding of the ways in which founders' pre-entry knowledge influences the evolution and performance of a start-up. Entrepreneurship emerges as a result of the individual-opportunity nexus (Shane, 2000). However, it is the pre-entry knowledge endowments of the founders that triggers the possibility of action and enables them to recognize an entrepreneurial opportunity (McMullen & Shepherd, 2006). In the three chapters of this dissertation, I review the existing literature on founder pre-entry knowledge and deepen our understanding of how founders' knowledge and early choices can have a sustained impact on a start-up's performance.

In the first chapter, I reviewed existing literature and identified some open questions and theoretical and empirical puzzles. In the second chapter, using the minimally invasive surgical devices (MIS) industry as the context, I explored the implications of early choices of a new venture's knowledge structure, specifically its technological complexity, on the subsequent development of the venture's knowledge trajectory and its eventual performance through successful product commercialization. I defined technological complexity as a recipe for developing a technology characterized by interdependencies among the ingredients. Since a venture's ability to manage complexity can be influenced by the knowledge derived from the founder as well as its own prior history, I considered the effect of each of these sources separately as factors influencing the ability of the venture to develop its technology and successfully launch a product.

In the third chapter, I focused specifically on VC-funded serial entrepreneurs across six high-tech industry contexts and investigated how knowledge gained through prior entrepreneurial experience can have a differential impact on different indicators of firm

performance. Knowledge gained through prior entrepreneurial experience shapes entrepreneurs' behavior and perceptions in important ways and while extant literature has largely focused on the positive effect of this knowledge on a firm's likelihood of achieving success, this study identifies important trade-offs that arise due to the myopic nature of this learning. By focusing attention on two important types of founder pre-entry knowledge – technological knowledge and market knowledge and two indicators of firm performance – invention impact and economic success, this study uncovered important contingencies that shape the extent and nature by which prior experience translates into subsequent performance.

Contributions

The dissertation as a whole contributes important insights to our cumulative understanding of why some start-ups succeed and others do not. Further, an important contribution that I make through this research is to bridge the literature on innovation as it relates to knowledge search and the literature on entrepreneurship as it relates to founder pre-entry knowledge. By recognizing that knowledge search strategies deeply imprint a new venture's development trajectory in technology intensive industries and linking this to founder pre-entry knowledge, I am able to shed light on heretofore unexamined mechanisms associating technology search strategies and start-up outcomes.

This research also helps to provide greater clarity on the role of context in shaping the value and relevance of founders' knowledge endowments. I examined start-up performance by taking a holistic view of success and considering several indicators of new venture performance. I investigated venture success in terms of success in product introduction, ability to create impactful knowledge and achieving a successful exit. An important conclusion that I draw from this analysis is that prior experience may have a differential impact on different indicators of a

firm's performance. For example, my research shows that while higher founder market knowledge helps to improve the likelihood of a firm's economic success, it also at the same time, constrains its likelihood of producing impactful knowledge. Thus I contend that subsequent research should pay greater attention to the relationship between different types of founders' knowledge and different indicators of firm performance and more broadly, by taking into account the role of context, to discern when prior experience is a good teacher and when it is not.

Another important contribution of this research is to deepen our understanding of the link between individual actions and organizational level outcomes. Founders' pre-founding experience conditions them to favor certain strategies and recipes for success. For example, as we find in chapter two, founders that have invented complex technologies are likely to found firms that in turn develop and produce complex knowledge. However, producing commercial products based on such technologies may be especially challenging, leading to heightened risk of failure to launch their first product. Similarly, in chapter three, we find that a serial entrepreneur's market knowledge mediates the relationship between their technological knowledge and successful firm exit. Thus the successful commercialization of a technology appears to be crucially contingent on an entrepreneur's understanding of the needs of the target market. Thus this research illustrates and deepens our understanding of how a firm's eventual success is determined by "the individuals who stand at the interface of … the firm and the external environment" (Cohen and Levinthal, 1990: p.132).

In conclusion, this dissertation made several important contributions to our understanding of how early founding conditions drive the evolution and eventual success of new ventures in technology intensive industries. Drawing on the landscape analogy often used in studies on technology search (Levinthal, 1997), the knowledge endowments of the venture's founders limits

how much of the total technological and market opportunities available to the venture, they are able to view. While some founders may see a broad portion of this opportunity landscape, others may see only a small portion. By advancing our understanding of the ways in which founder pre-entry knowledge constrains new venture strategic choices and identifying ways by which founders may loosen these constraints, this dissertation research takes another step towards opening up the black-box of how founding teams impact firm performance.

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