

**Social Capital, Cognitions, and Firm Innovation:
Theoretical Model and Empirical Studies**

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**Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State
University in partial fulfillment of the requirements for the degree of**

Doctor of Philosophy

in

Management

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June 1st, 2006

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**Keywords: Social capital, Cognition, Firm innovation, Theoretical model, Empirical
studies**

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ABSTRACT

Innovation is the central value of economic behavior. In this dissertation research, I attempt to explore the social and cognitive origins of firm innovation through three interrelated studies, by merging several research streams – managerial cognitions, social networks, and innovation, and collecting data through multiple methods – archives and surveys.

First, I proposed a social-cognitive view to study the sources of firm innovation. In the context of firm innovation, top management teams' cognitions or an entrepreneur's cognitions shape the way they use the social structure available to them, while the social structures influence the embedded actors' cognitions and ultimately strategic actions. Managers and entrepreneurs form collaborative partnerships aimed at innovation and competitiveness. During this dynamic social learning process, cognitive differences influence the formation of social capital and its realized benefits. The impact of social capital on innovation cannot be evaluated without understanding the individual cognitive characteristic first.

Next, I tested this theoretical model in two contexts. In the first empirical study, I derived firm-level hypotheses that link the top management team's cognitions, the firm's social capital, and the technological innovations. These hypotheses are tested on a sample of

U.S. semiconductor firms in the years 1991-1998. In the second empirical study, I derived similar hypotheses that link entrepreneur's cognitions, social capital and startup's technological innovations. A survey was conducted in both Pennsylvania and Virginia, targeting the entrepreneurial firms in technology industries. The hypotheses were empirically tested on a final sample of 70 U.S. small and medium-sized manufacturers. Two empirical studies supported some of the derived hypotheses and the findings have significant theoretical, empirical, and practical implications. In a diverse social network, actors' knowledge structure tends to be more complex, and more centralized. In addition, these studies indicate that both social capital and cognitive structure play important roles in technological innovation.

By distinguishing between cognitive structures, as well as social capital characteristics, and by investigating their effects on firm innovations, this dissertation extends the literature on organization theory, innovation research, entrepreneurship, and research methodologies. This dissertation research deepens our understanding of firm innovation, and opens a whole line of further research.

ACKNOWLEDGMENTS

Like the paths taken by many doctoral students to write their dissertations, my journey was not a smooth one, filled with many difficult challenges, a few disappointments and frustrations, and finally some “aha!” moments. When I began my journey to study the technological innovations in the summer of 2003, the research topic was international technology licensing. However, in the summer of 2004, after attempts to access the government data of U.S. and Japan in vain, I realized it was necessary to change to a controllable and manageable research topic.

During the 2004 Academy of Management Conference in New Orleans, I noticed an emerging and promising research stream – managerial cognitions. After going back to Virginia Tech, I searched the current literature on the relationship between managerial cognitions and firm innovations, but could not find enough relevant studies. At this time, Dr. Devi Gnyawali reminded me that there might be a linkage between managerial cognitions and social networks. Under the direction of my committee chair, Dr. Donald Hatfield, I did some research on competitive networks in the year of 2002. Therefore, I began to theorize the interrelations between social capital, managerial cognition, and technological innovation. For the next seven months, I rewrote the dissertation proposal and defended it in April 2005. During this period, Don and Devi gave me valuable advice on this research; two other committee members, Dr. Jim Lang and Dr. Theodore Fuller also gave me specific suggestions to improve my research. In another year, I completed this dissertation which consists of three interrelated studies on firm innovation. At the end of this journey, I really appreciate Don and Devi’s advice, support and considerations. And I would like to thank Dr. Lang and Dr. Fuller for taking the time in their busy

schedule to become a part of my dissertation committee and giving me insightful suggestions. In addition, I would like to thank members of the Virginia Tech Graduate Research Development Project (GRDP) committee who during the Spring 2005 semester awarded a \$375 grant for the completion of this study.

Throughout this journey, I also received generous support from my current employer, Penn State University at New Kensington. From course reduction to research assistance, the school did what they could to support my dissertation research. I feel fortunate to be a part of an institution that demonstrates a high level of commitment to its faculty members. To this end, I am very grateful to Dr. Arlene Hall, Director of Academic Affairs, and Dr. Michael McGinnis, a senior business faculty member at Penn State New Kensington.

On a final note, I am truly grateful to my family (my parents, husband, and sister) for their encouragement and help throughout this project. Their love and support were enormous sources of strength for me. And throughout my five years at Virginia Tech, Don was always there, willing to listen and help. I'm deeply grateful to Don not because of his position as my committee chair but because of his gracious heart.

TABLE OF CONTENTS

<i>LIST OF TABLES</i>	viii
<i>LIST OF FIGURES</i>	ix
<i>LIST OF APPENDICES</i>	x
<i>Chapter I INTRODUCTION</i>	1
Innovation, Social Capital, and Managerial Cognitions	1
Why Study Innovation?	1
Why Social Capital?	2
Why Cognitions?	2
Research Overview	4
The Organization of the Dissertation	4
<i>Chapter II RESEARCH ON INNOVATION, SOCIAL CAPITAL AND COGNITIONS</i>	6
Innovation Research	6
Social Capital Studies of Innovation	10
Cognitive Studies of Innovation	19
<i>Chapter III SOCIAL CAPITAL, COGNITIONS, AND FIRM INNOVATIONS: A THEORETICAL MODEL</i>	25
Social Capital and Cognitive Structure	25
Towards A Social-cognitive View of Innovation	31
Feedback Loop	36
A Dynamic Process	39
Discussion	40
<i>Chapter IV SOCIAL CAPITAL, MANAGERIAL COGNITIONS AND INNOVATION: EMPIRICAL EVIDENCE IN A HIGH-TECHNOLOGY INDUSTRY</i>	42
Hypotheses Development	42
Setting and Sample	48
Data and Variables	50
Analysis and Findings	57
Discussion	64
<i>Chapter V SOCIAL CAPITAL, ENTREPRENEURIAL COGNITIONS AND NEW VENTURE INNOVATION: A SURVEY OF TECHNOLOGY STARTUPS</i>	66
Hypotheses Development	66

Sample and Survey Design	71
Variables Operationalization	75
Analysis and Findings	82
Discussion.....	90
<i>Chapter VI CONCLUSION.....</i>	<i>92</i>
Summary of Major Findings.....	92
Answers to Research Questions	93
Contributions.....	95
Limitations and Directions for Future Research	98
<i>BIBLIOGRAPHY.....</i>	<i>100</i>
<i>APPENDICES</i>	<i>122</i>
Appendix A: Patent Classification Codes	122
Appendix B: A Multi-stage Computer-assisted Content Analysis of Presidents' Letters to Shareholders.....	123
Appendix C: Survey Questionnaire.....	124

LIST OF TABLES

Chapter IV Table 1: List of Semiconductor Firms Covered in the Analysis 1991-1998 .	49
Chapter IV Table 2: Themes discovered by common factor analysis (Year 1992).....	55
Chapter IV Table 3: Summary of Constructs, and Proxies.....	58
Chapter IV Table 4: Pearson Correlations ^a	59
Chapter IV Table 5: Pooled cross-sectional time series with fixed (firm) effects controls: Effects of Social Capital Diversity on Cognitive Centrality ^a	60
Chapter IV Table 6: Pooled cross-sectional time series with fixed effects controls: Effects of Social Capital Diversity and Cognitive Centrality on <i>Search Depth (exploitation)</i> ^a	61
Chapter IV Table 7: Pooled cross-sectional time series with fixed effects controls: Effects of Social Capital Diversity and Cognitive Centrality on <i>Search Scope (exploration)</i> ^a	63
Chapter V Table 1: Summary of Constructs, and Corresponding Proxies	84
Chapter V Table 2: Pearson Correlations ^a	85
Chapter V Table 3: Effect of Social Capital Diversity on Cognitive Complexity ^a	86
Chapter V Table 4: Effect of Social Capital Diversity on Cognitive Centrality ^a	87
Chapter V Table 5: Effects of Social Capital Diversity, Cognitive Centrality, and Cognitive Complexity on Degree of Innovativeness ^a	89

LIST OF FIGURES

Figure 1 Definition and Justification of Key Constructs	3
Figure 2 A Focused Literature Review: Representative Studies	24
Figure 3 Prototypes of Networks	26
Figure 4 Prototypes of Cognitive Structures.....	28
Figure 5 Social Capital, Cognitions and Innovation: A Theoretical Model	38
Figure 6 Hypotheses in the First Empirical Study	48
Figure 7 Hypotheses in the Second Empirical Study.....	71

LIST OF APPENDICES

Appendix A: Patent Classification Codes.....	122
Appendix B: A Multi-stage Computer-assisted Content Analysis of Presidents' Letters to Shareholders.....	123
Appendix C: Survey Questionnaire	124

Chapter I INTRODUCTION

Innovation, Social Capital, and Managerial Cognitions

Innovation is the driving force of economic growth. This dissertation follows the literature on social networks and organizational learning and attempts to incorporate the cognitive factors and social factors in the innovation research. A firm's social capital is an important source of firm innovations, and top management team or entrepreneur's cognitions of firm innovation also contribute to this process. A social-cognitive view of innovation is proposed and empirically tested in the setting of high-technology industries. This dissertation addressed a set of related questions regarding cognitions, social capital, and innovation. First, how do external social capital and internal cognitive structure influence each other in the process of firm innovation? Managerial cognitions are a key causal driver to the formation of different types of social capital, while different social capital influences the embedded actors' cognitive structures. The impact of social capital on firm performance cannot be evaluated without understanding the actors' cognitions first. Second, how does social capital influence firm innovation? Third, how does cognitive structures influence firm innovation? In examining these questions, I hope to address one fundamental question in strategic management: How do firms achieve innovation?

Why Study Innovation?

Scholars of earlier times, such as Adam Smith, Karl Marx, Paul Samuelson, and Alfred Marshall, argued that innovation plays a central role in economic growth and capitalism. Innovation is both the generation and the exploitation of new products, processes,

services and business practices. As a special kind of economic activity, innovation requires very special kinds of informational and coordination mechanisms (Teece, 1992). Technological innovation is an important source of differentiation in organizations (Nelson & Winter, 1982). A firm's competitive advantage rests not only on exploiting current technologies and resources for the benefit of efficiency, but also on exploring new opportunities (March, 1991; Teece, Pisano, & Shuen, 1997). This dissertation focuses on the sources and process of technological innovation.

Why Social Capital?

Social capital is defined as networks of relationships and assets located in these networks (Bourdieu, 1986; Burt, 1997; Coleman, 1988; Lin, 2001b). Along with financial capital and human capital, social capital has been shown to play an important role in firm performance. In dynamic industries, social capital is especially necessary to support innovative activities. In a competitive marketplace, the profitable commercialization of technology requires timely access to complementary assets. Study of the effects of various social networks on innovation output offers more insights into this process. In a homogeneous social network, firms focus on logical extension of what they have already succeeded in the past. In a diverse social network, firms' access to external heterogeneous knowledge and ideas enhances their explorative innovations.

Why Cognitions?

Cognitions are the knowledge structures or mental templates that actors impose on an information domain to give it form and meaning (Lyles & Schwenk, 1992; Walsh, 1995). The process of innovation is influenced by the cognitive mechanisms through which

people acquire, store, transform, and use information. Innovative activities arise from the actors' actions; understanding why and how these persons act as they do is essential to understanding the innovation process. Since minds propel actions, managerial cognition lies at the center of the strategic management process (Stubbart, 1989). This dissertation incorporates the top management team or entrepreneur's cognitions in the creation of a firm's social capital and explores their effects on innovation output by means of a theoretically rigorous and empirically testable approach.

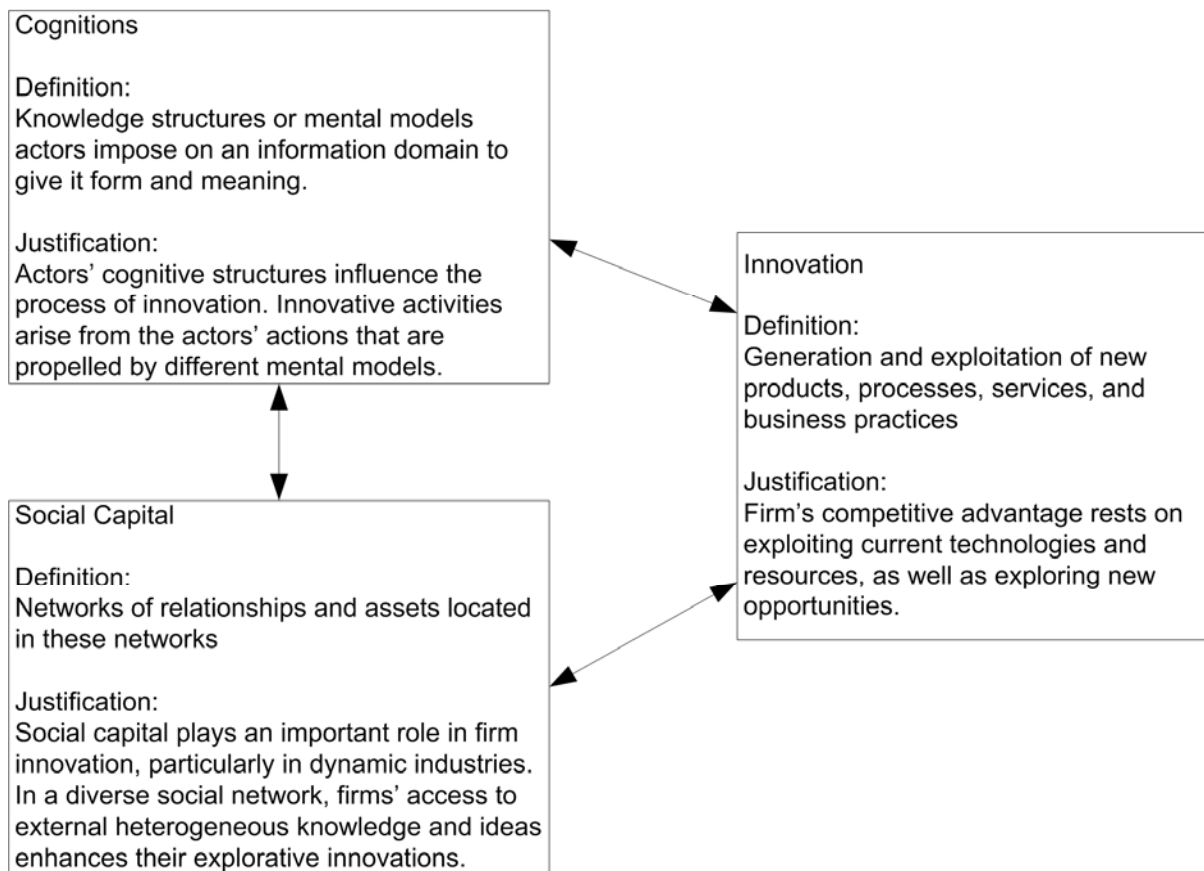


Figure 1 Definition and Justification of Key Constructs

Research Overview

The overall objective of this research is to explore the sources and processes of firm innovations, specifically, the independent and interactive effects of social capital and managerial cognitions on innovation output. First, I propose a social-cognitive view of innovation and developed propositions that link cognitions, social capital, and firm innovations. The theoretical model (Figure 5 on Page 38) incorporates social factors and cognitive factors in the study of firm innovations. Next, based on the proposed social-cognitive model of innovation, I derived a series of firm-level hypotheses linking managerial cognitions, social capital, and firm innovations. I tested these hypotheses on a sample of U.S. semiconductor firms in the years 1991-1998. In the second empirical study, I derived a series of firm-level hypotheses linking entrepreneurial cognitions, social capital, and firm innovations. These hypotheses were tested by using empirical data collected through a mail survey of technology new ventures in Pennsylvania and Virginia. These studies allow a comprehensive examination of firm innovation as affected by actors' cognitions and social capital.

The Organization of the Dissertation

The remainder of this dissertation is divided into five chapters. Chapter II forms the foundation for my research, presenting an overview of existing works in innovation, social capital, and firm innovation. Chapter III presents a social-cognitive model of innovation, from which a series of propositions are derived. Chapter IV presents an empirical test of the derived hypotheses linking managerial cognitions, social capital, and technological innovations, using archival analysis of a sample of U.S. semiconductor firms in the years 1991-1998. Chapter V presents an empirical test of the derived

hypotheses linking entrepreneurial cognitions, social capital, and innovations, using data collected through a survey of technology startups in Pennsylvania and Virginia. Chapter VI integrates the contributions made through the empirical studies and concludes by discussing the limitations of these studies and future directions for research.

Chapter II RESEARCH ON INNOVATION, SOCIAL CAPITAL AND COGNITIONS

This chapter presents a *focused* literature review of innovation research, social capital studies of innovation, and cognition studies of innovation. The theoretical model and empirical studies in the later chapters are built on the representative works reviewed in this chapter.

Innovation Research

The evolutionary process of enterprises is constantly disturbed by product and process innovations (Nelson et al., 1982; Schumpeter, 1934). Innovative behavior is a strategic activity by which organizations gain and lose competitive advantage (Jelinek & Schoonhoven, 1990; Von Hippel, 1988). Innovation is the implementation of new combinations of different resources in the firm (Drucker, 1998; Hargadon, 2002). Two types of innovation are distinguished: technological innovation and social innovation. This dissertation focuses on technological innovation at the firm level.

In technological innovation, firms conduct exploratory and exploitative search activities. Exploration and exploitation have been shown as fundamentally different search behaviors (Benner & Tushman, 2002; Katila & Ahuja, 2002; March, 1991). In exploitative search, a firm builds on its existing technological capabilities, whereas in exploratory search, a firm looks for new capabilities (March & Simon, 1958; Weick, 1979). This is a two-dimensional construct. A firm could leverage its existing knowledge base and explore new technological trajectory simultaneously (Christensen, 1997; Rosenkopf & Nerkar, 2001; Sorenson & Stuart, 2000).

Meanwhile, scholars identify an innovation as either radical or incremental by determining the degree of change associated with it (Ettlie, Bridges, & Okeefe, 1984; Normann, 1971). Radical innovations produce fundamental changes in the activities of an organization or an industry and represent clear departures from existing practices. Radical destructive innovations also significantly increase environmental uncertainty and result in the transformation of firms or industries (Meyer, Brooks, & Goes, 1990; Tushman & Anderson, 1986). On the contrary, incremental innovations mainly reinforce the existing capabilities of organizations (Dewar & Dutton, 1986; Ettlie et al., 1984; Henderson & Clark, 1990).

Several traditional research streams are relevant to innovation research. In evolutionary economics, the concepts of tacit knowledge and routines were tied to the dynamics of Schumpeterian competition (Nelson et al., 1982; Schumpeter, 1934). Firms compete primarily through a process of innovation. Organizational capacities are based on implicit routines that are developed over a period of time with repetition and practice. In economics, markets efficiently convey information through prices when the exchanged items are well specified and understood, and when the context of these exchanges is relatively stable. However, in the process of innovation, markets are not efficient in conveying information through prices because the knowledge that is exchanged is implicit and unspecified in an uncertain context (Cohen & Fields, 2000).

In transaction cost theory, hierarchies arise to internalize market transactions characterized by high transaction cost (Coase, 1937; Williamson, 1975). When a hierarchy is uncertain about the outcome of transactions and these transactions require asset-specific investments, the hierarchy tends to internalize these transactions in the

presence of opportunism and bounded rationality (Williamson, 1996). However, in the process of innovation, hierarchies are inefficient because the information needed is incomplete and dispersed across various individuals and firms (Cohen et al., 2000).

In organizational sociology, the system within which the economic or social exchanges are embedded generates value and meaning apart from the instrumental worth (Rumelt, Schendel, & Teece, 1994). The embedded members of a network engage in reciprocal exchange without expecting immediate benefits in return. Network exchange is not simultaneous and is not subject to the short-term rational calculations of a market transaction (Gopalakrishnan & Damanpour, 1997). In the process of innovation, shared values and mutual trust facilitate economic exchanges.

Technological developments and the rapid diffusion of new technology have changed the current business environments. In this new competitive environment, both new ventures and major corporations seek to exploit business opportunities by using proactive and innovative behaviors (Dess, Lumpkin, & McGee, 1999). Firms must learn how to create dynamic core competencies to exploit the environmental opportunities while minimizing the destructive effects of discontinuities and uncertainty (Lei, Hitt, & Bettis, 1996).

In organization learning literature, exploitation, or incremental improvements to knowledge, results in greater rates of success through practice; exploration, or radical extensions of knowledge, results in increased variation with reduced probability of success from each effort (March, 1991; McGrath, 2001). Knowledge is a strategic resource the firm can possess and on which sustainable competitive advantage can be built (Marsh & Ranft, 1999; Nonaka, 1994; Simonin, 1999). Learning promotes

comparative innovative efficiency. Firms must be able to identify, create and continuously manage knowledge, technological knowledge in particular, to generate value (Hitt, Ireland, & Lee, 2000). Technology is “a systematic body of knowledge about how natural and artificial things function and interact” (Itami & Numagami, 1992). Technology is a form of knowledge and technological change can be understood by examining knowledge development (Bettis & Hitt, 1995; Garud & Nayyar, 1994; Mokyr, 1990). Organizational arrangements that provide access to knowledge quickly and reliably produce competitive advantage (Nelson, 1990; Stinchcombe, 1990). Firm innovations are also shaped by strategic decisions and managerial controls. Managers make strategic choices among competing research ideas to advance them into product innovations. A strategy of concentrating innovation in new areas that are unrelated to the existing customer base or existing technologies is purely exploratory; whereas focusing new product innovation entirely around existing complementary assets is essentially exploitative (Danneels, 2002). In other words, exploitation builds on or extends the existing knowledge of a firm, while exploration requires new knowledge and capabilities. Exploration are often conducted by new entrants (Foster, 1986; Sull, Tedlow, & Rosenbloom, 1997), while exploitation are often chosen by established incumbents (Abernathy & Utterback, 1978; Tushman et al., 1986). The balance between exploration and exploitation is driven by strategic decisions to be an inventor or an early imitator, or a strategy to reduce risk by “sticking to the knitting” of existing core competences (Dosi, 1988). Managers control the innovation novelty path by selecting among the ideas that will be advanced into innovations, with an underlying dependence on the firm’s strategy to stick to existing competences and resources or to take risks in new areas.

Social Capital Studies of Innovation

Social capital refers to the resources contacts possess and the structure of contacts in a network (Burt, 1992). These actual or potential resources are embedded in social networks accessed and used by actors for actions (Lin, 2001b), which are linked to possession of a durable network of relationships, mutual acquaintance and recognition (Bourdieu, 1986). The term *social capital* was first used to describe the social networks one finds in mixed-use neighborhoods in large cities (Jacobs, 1961). This term was also used in a way that has general application to economic development (Coleman, 1986; Coleman, 1988). Different from *physical capital* and *human capital*, social capital exists in the structure of relations between and among actors, facilitating cooperation among embedded actors.

An actor's social capital has three dimensions: structural embeddedness, relational embeddedness, and resource embeddedness. Structural embeddedness is the structure of the overall network of relations (Granovetter, 1990). The structural properties include network size, density and diversity. Relational embeddedness is the extent to which economic actions are affected by the quality of actors' personal relations (Granovetter, 1990). The relational dimensions of dyadic ties include relational content (Burt, 1983a; Burt, 1997; Podolny & Baron, 1997), tie strength (Marsden & Campbell, 1984), and relational trust (Galunic & Moran, 1999; Tsai & Ghoshal, 1998). Resource embeddedness is the degree to which network contacts possess valuable resources (Bourdieu, 1986; Lai, Lin, & Leung, 1998; Lin & Dumin, 1986; Marsden & Hurlbert, 1988). Various resources should be available for instrumental mobilization (Granovetter, 1982; Lin, 2001a, 2001b). Actors must know existing resources embedded in the network, and their business

partners should put resources at each other's service. A firm's unique portfolio of tangible and intangible resources influences the rate and direction of its growth and diversification (Barney, 1991; Mahoney & Pandian, 1992; Penrose, 1959; Peteraf, 1993). A firm can achieve sustainable growth if its core competences (Hamel & Prahalad, 1994) cannot be easily imitated by competitors (Barney, 1991; Lippman & Rumelt, 1982). The heterogeneous structural, relational, and resource properties of networks lead to different firm performance (Batjargal, 2003). This dissertation focuses on two characteristics of social capital: density and diversity.

Previous research has studied the role of social capital in the social and economic phenomena. Coleman (1988) explained the concept of social capital, described its forms, and examined the social structural conditions from which it arises. In the analysis of dropouts from high school, he illustrates that information diffusion is enhanced when a network is tightly inter-connected and closed (Coleman, 1988). Gargiulo and Benassi (2000) reviewed three theories that lead to opposite predictions on how the structure of an actor's network may affect his ability to adapt that network to a significant change in task environment. Their study shows that managers with cohesive communication networks were less likely to adapt these networks to the change in coordination requirements prompted by their new assignments (Gargiulo & Benassi, 2000). Kale, Singh, and Perlmutter (2000) argued that one of the main reasons that firms participate in alliances is to learn know-how and capabilities from their alliance partners. At the same time firms want to protect themselves from the opportunistic behavior of their partner to retain their own core proprietary assets (Kale, Singh, & Perlmutter, 2000). Most research has generally viewed the achievement of these objectives as mutually exclusive. In contrast,

using large-sample survey data, their study provided empirical evidence that when firms build relational capital in conjunction with an integrative approach to managing conflict, they are able to achieve both objectives simultaneously. Relational capital based on mutual trust and interaction at the individual level between alliance partners creates a basis for learning and know-how transfer across the exchange interface. At the same time, it curbs opportunistic behavior of alliance partners, thus preventing the leakage of critical know-how between them.

Reagans and Zuckerman (2001) reframes demographic diversity in terms of the network variables that reflect distinct forms of social capital. The authors predicted that decreased network density lowers a team's capacity for coordination, whereas high network heterogeneity enjoys an enhanced learning capability. Using the data on the social networks, organizational tenure, and productivity of 224 corporate R&D teams, they tested these hypotheses, and the findings support most of the hypotheses (Reagans & Zuckerman, 2001). Larson (1992) examines the conditions under which successful partnership networks were formed by four entrepreneurial companies. An inductive field study of a sample of dyadic relationships established by high-growth entrepreneurial firms suggests that a network organizational form can be cultivated by smaller companies and the data gathered indicate that these alliances do not form by chance. They are patterned, predictable exchange structures that can be replicated and used to improve a firm's competitive position (Larson, 1992).

Recent work on social networks has emphasized the importance of social capital or business networks for innovativeness. With increasingly modular products and distributed knowledge (Baldwin & Clark, 2000), firms recognize a need to collaborate

with other firms both formally and informally. When knowledge is broadly distributed, the locus of innovation resides in a network of inter-organizational relationships (Powell, Koput, & Smith-Doerr, 1996). Many scientific and technological breakthroughs result from numerous contributions of many actors working in networks (Bougrain & Haudeville, 2002). Furthermore, an emerging research stream has looked to patterns of relationships as predictors of innovation. It focuses on whom an individual knows rather than his or her personal characteristics. An interesting idea is that the important aspect of weak relations is not their weakness but rather their diversity. Most of us have close friends who look like us and like each other, but we typically maintain casual relations with a much broader set of individuals (Burt, 1992). This diversity can stimulate innovation by bringing individuals in contact with a broader range of information (Burt, 2004).

For example, the value of collaboration for innovation has been shown in the biotechnology industry (Baum, Calabrese, & Silverman, 2000; Shan, Walker, & Kogut, 1994), global chemicals industries (Ahuja, 2000b), service industries¹ (Elg & Johansson, 1997; Knights, Murray, & Willmott, 1993), primary industries² (Jacquier-Roux & Bourgeois, 2002); Nieuwenhuis 2002), manufacturing industries³ (Biemans, 1991; Grotz & Braun, 1997; Hyun, 1994; Izushi, 1997; Shaw, 1993), and other high-tech industries⁴ (Coles, Harris, & Dickson, 2003; Frenken, 2000; Reed & Walsh, 2002; Streb, 2003).

¹ Financial services and food.

² Agriculture; energy; oil and gas.

³ Automobile components; ceramics manufacturing; clothing; mechanical engineering; packaging machine industry.

⁴ Aerospace and defense; biotechnology; electronics; embryonics; enzymes; home automation; petrochemicals; plastics; robotics; semiconductors; software; telecommunications.

Next I review the recent social capital studies of innovation at different levels of analysis: individual level, subunit level, firm level, and regional level.

At the *individual* level, people tend to interact more with their own kind as defined by race, gender, educational class, organizational unit, and other individual characteristics, whether by preference or induced by opportunity constraints (McPherson & Smith-Lovin, 1987). Recent organizational research has studied this tendency's effects on group and individual performance (Ibarra, 1992; Krackhardt & Stern, 1988; Reagans et al., 2001). On the one hand, interaction in a homogeneous network is efficient to the extent that homogeneity (a) facilitates transmission of tacit knowledge (Cross, Borgatti, & Barker, 2001), (b) simplifies coordination (Ancona & Caldwell, 1992; O'Reilly, Caldwell, & Barnett, 1989), and (c) avoids potential conflicts (Pelled, Eisenhardt, & Xin, 1999; Pfeffer, 1983). On the other hand, this exclusive communication with people similar to oneself prevents a group from reaping the benefits of diversity (Krackhardt et al., 1988). Burt (1992) illustrates that an actor's informational advantage will be maximized when network ties are diverse and loosely interconnected. Participating in closed networks increases reliability of information, while participating in many is consistent with an information searching strategy (Burt, 1992). In a recent article, Burt (2004) outlines the mechanism by which brokerage provides social capital. Opinion and behavior are more homogeneous within than between groups, so people connected across groups are more familiar with alternative ways of thinking and behaving. Brokerage across the structural holes between groups provides a vision of options otherwise unseen, which is the mechanism by which brokerage becomes social capital (Burt, 2004). In this article, he also reviewed evidence consistent with the hypothesis, and analyzed the networks around

managers in a large American electronics company. Another recent study (Perry-Smith & Shalley, 2003) explores the association between the context of social relationships and individual creativity. It goes beyond a one-dimensional treatment of social relationships, highlighting the importance of both static and dynamic social network concepts. The authors argue that weaker ties are generally but not always beneficial for creativity, proposes the network positions that facilitate and constrain creative work, and describes 3 moderators (the extent of social relationships, the character of relationships in terms of their strength, and the extent they span boundaries). They also presented a spiraling model to capture the cyclical relationship between creativity and network position.

At the *subunit* level, within an organization, there is a tension between search and transfer abilities: though large networks of casual contacts offer R&D teams the best odds of finding the expertise they need within the firm, strong relations provide a better social infrastructure for the actual transfer of this information from one team to another (Hansen, 1999). Drawing on a network perspective on organizational learning, Tsai (2001) argues that organizational units can produce more innovations and enjoy better performance if they occupy central network positions that provide access to new knowledge developed by other units. This effect, however, depends on units' absorptive capacity, or ability to successfully replicate new knowledge. Data from 24 business units in a petrochemical company and 36 business units in a food-manufacturing company show that the interaction between absorptive capacity and network position has significant, positive effects on business unit innovation and performance (Tsai, 2001).

At the *firm* level, social capital can influence firm survival (Uzzi, 1996), firm performance (Baker 1990), inter-firm alliances (Gulati, 1995), rate of IPO (Stuart, Hoang,

& Hybels, 1999), product innovation (Tsai et al., 1998), industry-wide network formation (Walker, Kogut, & Shan, 1997), and the quality and quantity of innovation (Ahuja, 2000a; Powell et al., 1996; Shan et al., 1994).

A detailed survey of 4564 firms in the Central Europe suggests that firms that do not supplement their internal resources and competence with complementary external resources and knowledge show a lower capability for realizing innovations (Gemünden, Heydebreck, & Herden, 1992). Based on the assumption that intensity and structure are the most important dimensions of a firm's technological network, another study (Gemünden, Ritter, & Heydebreck, 1996) identifies seven different types of technology-oriented network configurations. Drawing upon a database of 321 high-tech companies, it is shown that innovation success is significantly correlated with a firm's technological network. Product and process innovations are shown to demand different types of network configurations.

Stuart (2000) investigates the relationship between inter-firm technology alliances and firm performance. It argues that alliances are access relationships, and therefore that the advantages which a focal firm derives from a portfolio of strategic coalitions depend upon the resource profiles of its alliance partners. An analysis of U.S. semiconductor firms supports the hypotheses that organizations with large and innovative alliance partners perform better than otherwise comparable firms that lack such partners (Stuart, 2000). Baum et al. (2000) combines theory and research on alliance networks and on new firms to investigate the impact of variation in startups' alliance network composition on their early performance. The authors hypothesize that startups can enhance their early performance by 1) establishing alliances, 2) configuring them into an efficient network

that provides access to diverse information and capabilities with minimum costs of redundancy, conflict and complexity, and 3) judiciously allying with potential rivals that provide more opportunity for learning and less risk of intra-alliance rivalry. An analysis of Canadian biotech startups' performance provides broad support for these hypotheses, especially as they relate to innovative performance (Baum et al., 2000). Powell et al. (1996) argued that when the knowledge base of an industry is both complex and expanding and the sources of expertise are widely dispersed, the locus of innovation will be found in networks of learning, rather than in individual firms. A network approach to organizational learning is developed, and a firm-level, longitudinal hypotheses are derived that link research and development alliances, experience with managing inter-firm relationships, network position, rates of growth and portfolios of collaborative activities. These hypotheses are tested on a sample of 225 biotechnology firms in the years 1990-1994. Results support a learning view and have broad implications for future theoretical and empirical research (Powell et al., 1996).

At the *regional* level, Saxenian (1994) has attributed the divergence between the ascendant Silicon Valley and the then declining Route 128 (Boston) economies to the greater mobility of engineers, and the consequent sharing of information, in Silicon Valley (Saxenian, 1994). By building on the dense networks of social relationships that were created and then abandoned by the established semiconductor firms, this new wave of semiconductor start-ups is creating a new Silicon Valley - one that fosters collaboration and reciprocal innovation among networks of specialist producers (Saxenian, 1990).

Furthermore, scholars have studied the relationship between the type of partner firms engaged in networking and the type of innovation occurring. For example, incremental innovators rely more frequently on their customers as innovation partners (Biemans, 1991; Romijn & Albaladejo, 2002), whereas firms that have products new to a market are more likely to collaborate with suppliers and consultants (Baiman, Rajan, & Kanodia, 2002; Ragatz, Handfield, & Scannell, 1997; Romijn et al., 2002). More advanced innovators with more radical innovations have more interaction with universities (Hausler, Hohn, & Lutz, 1994; Liyanage, 1995; Romijn et al., 2002). Firms that do not network possess much lower levels of competence in innovation (Gemünden et al., 1992; Ritter & Gemünden, 2003).

In conclusion, the evidence has shown that the innovation process, particularly exploratory innovation processes, benefits from engagement with a diverse range of partners. This engagement allows for the integration of different information, knowledge bases, behaviors and way of thinking. Formal and informal communication between people with different information, skills and values increases the possibility of novel combinations of knowledge (Conway, 1995). However, more risk-averse firms tend to link their innovation activities and networking relationships to customers, because knowledge of clients' demands reduces the risk of failure for the innovating firm. In this case, innovation is more exploitative, and productivity gains are more modest. This suggests a direct relationship between different networking activity and technological innovation.

Cognitive Studies of Innovation

Cognitive psychology (Neisser, 1967) helps explain the mental processes by which individuals interact with other people and the embedded environment. Social cognition theory (Fiske & Taylor, 1984) has been developed to specifically explain the individual behavior in this person-environment interaction. This theory introduces the idea of knowledge structures: mental models are ordered in such a way as to optimize personal effectiveness within given situations. In this dissertation, cognitions are defined as the managers' or entrepreneurs' mental reflections of a certain phenomenon, namely, the process of innovation.

Cognitive studies explore the cognitive processes that lie behind strategic choices. As a complement of the theory of rational choice, cognitive science has attempted to explain why or how economic decisions happen in an uncertain and subjective world (Kahneman, Slovic, & Tversky, 1982; Simon, 1957; Smircich & Stubbart, 1985). As thinking drives strategy-making, managerial cognition resides at the core of the strategic management process (Stubbart, 1989). Managers take strategic action intentionally to respond to the changing environment.

Managerial cognitive structures shape firm strategies for growth because the management team's conceptualization and employment of the firm's resource base influence the direction of expansion. Managers pursue competitive actions and deploy resources in a way that is consistent with their mental models of the firm's capabilities and with the competitive threats that they believe it faces. The determinants of the growth and direction of a firm are the productive capabilities that are engendered by resources interacting with managerial cognitive frameworks instead of the actual resources

themselves (Mahoney et al., 1992; Penrose, 1959; Porac, Thomas, Wilson, Paton, & Kanfer, 1995).

Innovation is a dynamic social learning process. Actors continuously assimilate information and knowledge from the others they interact with. As learning depends on experimentation and feedback, learning opportunities tend to be local to previous knowledge (Teece et al., 1997). Actors with more diversity of training and experience will create ideas with greater novelty than individuals with access to a more narrow pool of knowledge. Demographic differences that help explain the origins of homogeneous and diverse network performance are assumed to reflect underlying differences in cognition (Lawrence, 1997). The innovation period is rich in information about the definition of identities and the establishment of social roles (Harrison & Laberge, 2002). Social interaction plays a critical role in firm innovation, such as technology adoption (Fulk, 1993; Pinch & Bijker, 1986; Wilkinson, 1983).

Scholars have studied the role of management cognition in shaping organizational actions. Weick (1990) argues that new technologies are subject to a variety of interpretations and require 'sensemaking' in order to be managed (Weick, 1990). Lowstedt (1985) suggests that researchers looking for direct relations between technology and organization have ignored the cognitions of principal actors, which are crucial in mediating these relations. Since organizations and technologies are socially constructed by the people that describe and interpret organizations, there is no objective 'real' organization or technology independent of the cognitions of the people involved. People design technology and organization in keeping with their perceptions and explanatory frameworks (Lowstedt, 1985).

Swan (1995) describes the nature and importance of knowledge bases and cognitions for decisions about technological innovation and suggests how knowledge and cognitions can be explored using process research (Swan, 1995). In another study, Swan and Newell (1994) used a cognitive mapping methodology to reveal managers' beliefs about the causes of and effects of a particular type of technological innovation. These managers' beliefs are compared with suggestions made in the academic literature about the factors that influence a firms' level of innovation. Factors which, according to the academic literature, increase the likelihood of innovation were not believed to be important direct causes by these managers. These managers saw involvement in professional associations as a very important causal factor in innovation in production and inventory control. Other factors seen to be direct causes were the ratio of professional and technical staff to others in the firm, the promotion activities of vendors, and the competitors' levels of technology (Swan & Newell, 1994). Swan (1997) also emphasized the importance of cognitions in decisions about technological innovation. Because of the lack of availability of research tools and techniques, cognitive processes have been under emphasized in empirical work on technological innovation. The author reviewed the cognitive mapping methodologies, evaluated their limitations, and argued that a distinction should be made between cognitive maps and the output of mapping techniques (Swan, 1997).

Kaplan, Murray and Henderson (2003) attempted to link top management mental models to strategic choice in the face of discontinuous innovation. This paper uses 23 years of data covering 15 major pharmaceutical firms to explore the degree to which each firm's responses to the revolution in biotechnology was shaped by the senior team's recognition of biotechnology's importance. The findings suggest that cognition at the most senior

level can play a critical role in shaping established firms' response to discontinuities (Kaplan, Murray, & Henderson, 2003). Jelinek and Litterer (1994) proposed a cognitive theory of organizations that is able to link individual level phenomenon (e.g. cognitions and actions) with organizational level phenomena (e.g. output, coordinated actions, organizational change and organizational learning). An individual's beliefs are not just noise in the organizational decision-making process but they may actually guide the direction of an organizational decision, and the actions that occur as a result of that decision shape and modify the beliefs of the individual (Jelinek & Litterer, 1994).

Another research paradigm worth mentioning is the entrepreneurial cognition research that emerged in the early 1990s. The entrepreneur influences the performance of the new venture (Herron, 1990; Kunkel, 1991; McDougall, 1987; Sandberg, 1986; Shane & Venkataraman, 2000) through certain individual characteristics (Cooper, Willard, & Woo, 1986; MacMillan & Day, 1987; Sandberg, 1986), such as entrepreneurial skill and skill propensity (Herron, 1990). Trait-based research (Coulton & Udell, 1976; McClelland, 1965) has attempted to describe the entrepreneurial personality as a key factor in new venture formation and performance. However, no individual-level attributes or behaviors have been found to explain the differences between entrepreneurs and other members of society in a consistent and robust way (Busenitz & Barney, 1997). Entrepreneurship research can further explore the possibilities that are offered by social cognition and managerial cognition (Mitchell, Busenitz, Lant, & McDougall, 2002). Using the sciences of complexity and cognition, Kagan explored the resistance of business owners to accepting consultant advice (Kagan, 1995). Of special interest are the psychological and creative processes underlying entrepreneurship. The hypothesis is that during crisis

periods featuring innovation and growth, personal and business dynamics exhibit non-linear and mutually reinforcing characteristics.

Figure 2 presents a diagram of my focused literature review of innovation research, social capital studies of innovation, and cognition studies of innovation.

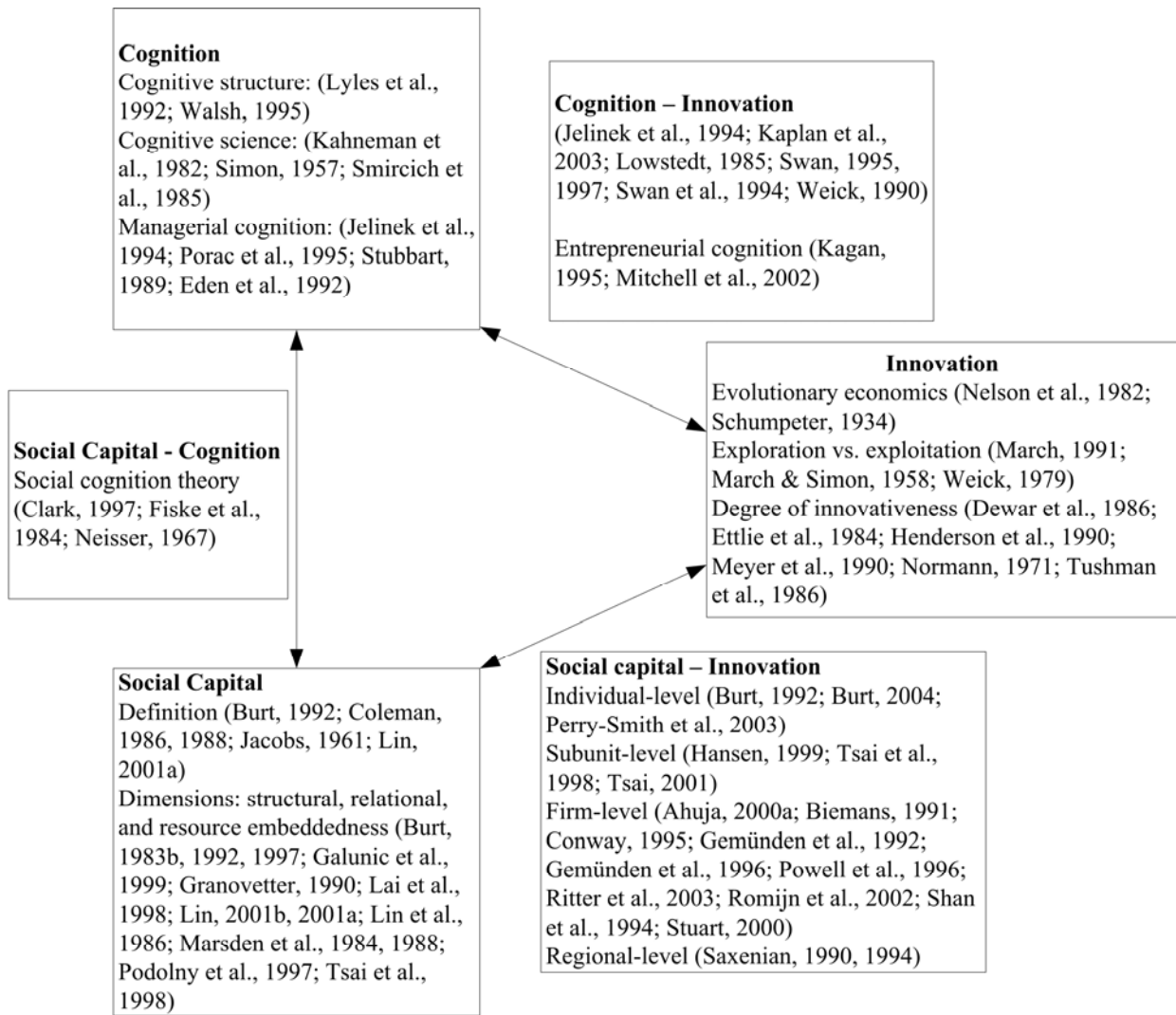


Figure 2 A Focused Literature Review: Representative Studies

Chapter III SOCIAL CAPITAL, COGNITIONS, AND FIRM INNOVATIONS: A

THEORETICAL MODEL

The research question of this dissertation is how firms achieve innovation? Innovation is defined as the generation and the exploitation of new products, processes, services and business practices. Specifically, it is “the development and implementation of new ideas by people who over time engage in transactions with others in an institutional context” (Van de Ven, 1986). During the process of acquiring and translating new ideas into practice, people’s internal cognitions and external relations play important roles. My primary interest in this dissertation is to integrate managerial cognition studies with social networks studies to investigate the origins of firm innovation.

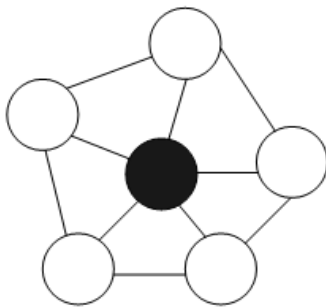
Social Capital and Cognitive Structure

A firm is embedded in its external social network. Social capital derives from a firm’s business network and is the means by which reciprocal exchange occurs in that network. Networks can be characterized along two dimensions: structure and content. Network structure refers to the way in which the relationships between the embedded actors are arranged. A structural property is network density – the extent to which the actors are connected to each other. Network content refers to the characteristics or attributes of the members embedded in the network. At the network level, network heterogeneity or diversity describes the extent to which each member’s attributes are different to other members. The content and structure of networks are conceptually and empirically distinct,

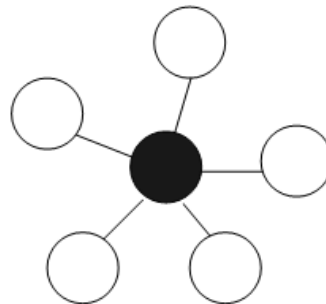
and both can influence the nature and the transfer of resources. Figure 3 presents four prototypes of networks varying in density and diversity (Yoo, 2003).

Although network density and diversity are conceptually distinct, there are correlations between network structures and contents. Dense networks have been shown to be correlated with homogeneity whereas sparse networks are more likely to be correlated with diversity (Yoo, 2003). Below I discuss the dense and homogeneous networks together as are sparse and diverse networks.

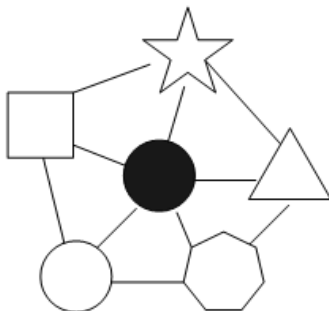
A. Dense, homogeneous network



B. Sparse, homogeneous network



C. Dense, heterogeneous network



D. Sparse, heterogeneous network

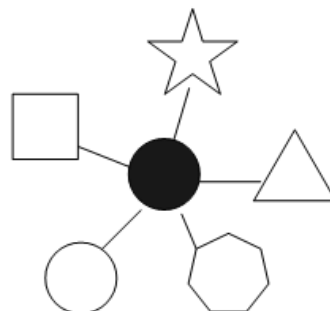
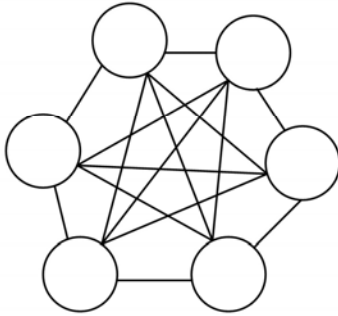


Figure 3 Prototypes of Networks

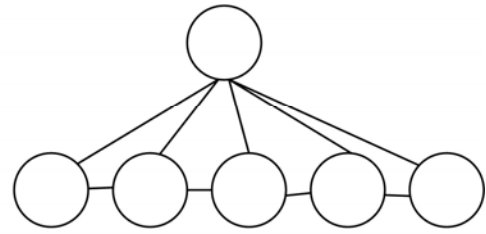
Members of a network form strong and weak ties to transmit knowledge among them. Homogeneous networks of cohesive and frequent social relationships improve cooperation and optimization of network tasks; however, they lack flexibility and the ability for creative problem solving (Reagans et al., 2001). On the other hand, diverse networks of sparse and infrequent social relationships are responsive to changing market conditions, provide access to new resources and ideas, and promote innovation (Gargiulo et al., 2000; Reagans et al., 2001); however, diverse networks lack the cohesiveness, trust, coordination and task specializations of homogeneous networks.

Cognitions are actors' mental reflections of a certain phenomenon, innovation in this study. With limited information processing capability, managers of an embedded network are unable to perceive the environment precisely and interpret information perfectly, particularly in a complex and uncertain environment. Their mental models change through adaptation and learning. Two cognitive characteristics are relevant to strategic flexibility: complexity and centrality. Complexity reflects the level of differentiation and integration in an actor's mental model (Walsh, 1995). Centrality reflects the level of focus and hierarchy in an actor's mental model (Eden, Ackermann, & Cropper, 1992). Complexity measures an actor's information-processing capability of capturing a broad collection of environmental, strategic and organizational concepts. Centrality measures an actor's tendency to centralize a strategy frame around a few core concepts. Figure 4 presents four prototypes of cognitive structures varying in centrality and complexity.

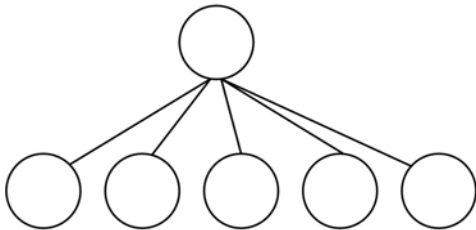
A. Complex cognitive structure with less centrality



B. Complex cognitive structure with more centrality



C. Centralized cognitive structure with less complexity



D. Non-centralized and non-complex cognitive structure

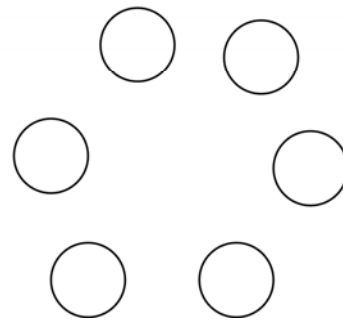


Figure 4 Prototypes of Cognitive Structures

In a social network, actors outsource the cognitive tasks to their relationships (Clark, 1997). An actor's social network is a decision-making entity, providing the fact premises and value premises upon which the actors rely in decision-making. Knowledge and information are dispersed among the actors embedded in the network. In a homogeneous social network, groups diffuse shared beliefs and social norms. Actors embedded in this network share and learn similar information and knowledge, promoting efficient and specialized use of resources. For example, managers in the same industry are similar in

cognition (Huff, 1982; Porac et al., 1995; Reger & Huff, 1993; Spender, 1989). Managers think and act similarly by two mechanisms: (1) collectively established ‘scaffolding’ (Clark, 1997), such as industry standards; and (2) identical solution provided by outside organizations, such as consulting firms, market research firms, and accounting firms. On the contrary, actors embedded in a diverse network are more likely to maximize the non-redundant information received through his contacts. This information diversity increases the possibility of the actors’ comprehension of a business context or phenomenon from multiple perspectives. Furthermore, this information diversity enhances the actors’ ability to differentiate the core concepts from the peripheral concepts. Diverse information and knowledge assimilated from different social relations may create information overload. The actor is more likely to develop a hierarchical cognitive structure to process efficiently these diverse information and knowledge.

Proposition 1a: In a sparse and diverse social network, the embedded actor’s cognitive structure is more likely to be more complex and more centralized.

Proposition 1b: In a dense and homogeneous social network, the embedded actor’s cognitive structure is more likely to be less complex and less centralized.

Simultaneously, an actor actively searches for new relationships to outsource the cognitive tasks. A network is a series of social relations with a specific content (Emirbayer & Goodwin, 1994). Actors’ narratives describe links in the network (White, 1992). Only an approach that brings human agency into the network analysis can adequately explain the formation, reproduction, and transformation of networks themselves. In the high technology industries, business networks are constantly changing to respond to the new environment. Interacting individuals influence each other to

produce homogeneity of beliefs (Carley, 1991; Friedkin & Johnsen, 1990, 1999; Kilduff & Corley, 2000b).

An actor's cognitive characteristics influence his networking process. Thinking drives strategy making. Networking is a key strategic action and a process of an individual's interacting with the environment. Resources flow through social ties (Lin, 2001b; Snijders & Bosker, 1999). An actor, such as an entrepreneur (Baron & Markman, 2003; Shane & Stuart, 2002), actively establishes ties through which information and aid flow. Human actors with different cognitive structures play a critical role in the formation of different types of social networks. People differ in discovering the benefits of network homogeneity and diversity. An actor with increasingly complex cognitions is more likely to discover and access the new productive resource opportunities from his contacts. This greater heterogeneity of resource choices motivates the actor to construct a diverse social network. Reciprocally, the development of a diverse network can positively reinforce the complexity that initiated this network structure. Therefore, an actor with more complex cognitions is more likely to construct a diverse network, and create new resource opportunities because heterogeneous knowledge stimulates persistent innovations. Furthermore, actors with more centralized cognitive structures are more efficient to establish ties with diverse social contacts because they are able to differentiate the key social relations from the other social relations for the peripheral factors.

Proposition 2a: An actor with a more complex and more centralized cognitive structure is more likely to construct a sparse and diverse social network.

In contrast, an actor with less complex and less centralized cognitive structure is more likely to form a dense and homogeneous social network because they are less able to

differentiate the key social relations from the other social relations. Individuals are more likely to form cohesive network relationships with individuals having similar knowledge and experience than with individuals of differing knowledge and experience (Coleman, 1988; Granovetter, 1983; McPherson, Popielarz, & Drobnic, 1992). A less complex cognitive structure means these actors are less likely to interact with others with different knowledge and experience. Furthermore, a less centralized cognitive structure means these actors are less efficient in establishing diverse social relations. This inefficiency means they are more likely to interact with similar others.

Proposition 2a: An actor with a more centralized cognitive structure is more likely to construct a dense and homogeneous social network.

Towards A Social-cognitive View of Innovation

In organizational learning literature, innovations are differentiated along two dimensions: exploration and exploitation (Benner et al., 2002; Katila et al., 2002; March, 1991).

Exploitation is refinement and extension of the existing competencies; whereas exploration is experimentation with new alternatives (March et al., 1958; Weick, 1979).

This is a two-dimensional construct. A firm could leverage its existing knowledge base and explore new technological trajectory simultaneously (Christensen, 1997; Rosenkopf et al., 2001; Sorenson et al., 2000). Different innovation activities require different information, reference points, and work routines. Next I will discuss how a firm's external social ties and internal cognitive structures influence these latent factors.

In firm innovation, forms of exchange are more dependent on relationships and partners' reputation, and less guided by authority and prices (Cohen et al., 2000). Networks are better suited to the coordination of knowledge intensive, high technology production than

are either markets or hierarchy (Adler, 2001; Powell, 1990). Markets fail to function well in the allocation of knowledge due to incomplete information and the public goods aspect of knowledge (Robertson & Langlois, 1995; Stiglitz, 1994). Hierarchies are well suited for mass production and distribution, but it is difficult for an authority to bring widely spread and individually held knowledge to the center. Instead, networks are particularly well suited to the exchange of commodities whose value is difficult to measure, such as knowledge and technological know-how. In the entrepreneurial context, contact resources together with structural and relational dimensions of networks have significant impact on firm performance (Batjargal, 2003).

Actions of economic agents are embedded in concrete, ongoing systems of social relations, and these relations facilitate and constrain agents' profit and rent-seeking actions (Granovetter, 1985). Members of a network learn through networks to stay current in a rapidly changing environment. Collaboration enhances organizational learning (Dodgson, 1993; Hamel, 1991). In a homogeneous network, actors' business contacts provide similar information about the product, supply markets, technology, and changes in the external environment. Every actor is directly or indirectly connected to every other by cohesive and frequent social interactions (Coleman, 1988; Gargiulo et al., 2000; Kilduff, Angelmar, & Mehra, 2000a; Reagans et al., 2001). This creates a high density of social relationships that produces homogenous and clustering behaviors (Gargiulo et al., 2000; Granovetter, 1983).

Moreover, the business network provides a context in which the managers can observe and emulate similar firms. When facing a choice with limited information, one common heuristic is to emulate the behavior of others (Gigerenzer & Todd, 1999). In a

homogeneous network, a firm tends to imitate similar firms' strategies and focus on increasing efficiencies in resource use.

In addition, an organization is routine based, history dependent, and target oriented (Levitt & March, 1988). The business network provides routines that can be directly made part of or amendments to the firm's current routines. Meanwhile, an employee's tasks and responsibilities are formalized into a written job description. The technical standards often go beyond design specifications to mandate specific routines. A standard business routine is more likely to emerge in a homogeneous business network, and members are more inclined to adopt it. However, a standardized business process management influences negatively the firm's exploratory innovation output (Benner et al., 2002).

Through sharing similar information and resources, imitating similar firms, and standardizing organizational routines, a firm embedded in a homogeneous network is more likely to be exploitative in innovation activities.

Proposition 3a: A firm embedded in a dense and homogeneous network is more likely to conduct exploitative search in technological innovations.

However, structural-hole theory suggests that the benefits of diverse information connections outweigh the mutual coordination and specialization benefits of homogeneous networks (Burt, 1997; Gargiulo et al., 2000; Perry-Smith & Shalley, 2003). In a diverse social network, members share non-redundant information and knowledge. Diverse networks benefit from brokering dispersed knowledge and information sources. Actors access new information, ideas, and resources that are not available in a homogeneous network (Burt, 1997; Gargiulo et al., 2000; Perry-Smith et al., 2003).

Because information transmitted through diverse networks is novel, diverse networks have a greater capacity to discover new productive opportunities and productive relationships (Burt, 1997; Powell et al., 1996). New ideas and knowledge can be accessed and recombined from non-redundant sources; consequently, diverse networks provide benefits of creativity and innovation (Granovetter, 1983; Perry-Smith et al., 2003; Reagans et al., 2001). In industries with rapid technological developments, such as biotechnology, frontier research can be more quickly adopted in networks consisting of diverse collaborations (Powell et al., 1996).

Moreover, a firm has various companies to imitate. Multiple reference points enable the company to explore new productive resources opportunities. Furthermore, a standard business routine is less likely to emerge in a diverse social network. Lack of a standardized business process management influences positively the firm's exploratory innovation output (Benner et al., 2002).

Proposition 3b: A firm embedded in a sparse and diverse network is more likely to conduct exploratory search in technological innovations.

Meanwhile, actors construct the innovation networks. An innovation is established as a result of exchanges of knowledge and ideas by individual actors or groups mobilized through legitimization activities, depending on given internal and external contexts (Pettigrew, 1985, 1990). People always operate in local situations in the context of interactions (Knorr-Cetina, 1981). To understand the sources and process of innovation, cognitive factors have to be incorporated into the social network studies. An actor's cognitive characteristics influence his process of receiving information, seeking reference points, and establishing work routines.

Actors construct knowledge structures consisting of organized knowledge about an information environment. These knowledge structures enable the actors to interpret this environment and take actions (Walsh, 1995). Knowledge structures are discussed in terms of frames of reference (March et al., 1958), cognitive maps (Axelrod, 1976b), and industry recipes (Spender, 1989). Managers and entrepreneurs create models of the world in their minds and use these models to simplify the complex environment. Based on the assumption that actors' mental representations guide cognition and actions relative to strategic choices, an actor with increasingly complex cognitions is more alert to various types of information and new productive resources opportunities. During the process of interacting with a technology, actors' cognitions help them construct different interpretations of the technology (Bijker, Pinch, & Hughes, 1990; Bloomfield, 1986; Woolgar, 1981). This social construction of technologies influences the process of firm innovation.

An actor with complex cognitions tends to pay more attention to the different reference firms. Learning from diverse sources enables the firm to build a diverse knowledge base, ultimately creating new technologies. In addition, actors who perceive firm innovation from multiple perspectives are less constrained by standard routines. They are more flexible with the process management; therefore, the work routines are less likely to be standardized. Diverse information flow, multiple reference points, and flexible process management ultimately enable the firm to be more exploratory in firm innovations.

Proposition 4a: The actors' cognitive complexity is associated positively with the firm's exploratory search in technological innovations.

Furthermore, an actor with a centralized cognitive structure selectively receives certain information and knowledge relevant to the core concepts and peripheral concepts. This efficiency enhances the actor's ability to assimilate more information and knowledge to explore new productive resources. This hierarchical cognitive structure enables the actor to imitate diverse reference companies for different factors. Actors are more alert to the environmental changes, while the ability of differentiating factors enables them to change the current organizational routines more quickly.

Proposition 4b: The actors' cognitive centrality is associated positively with the firm's exploratory search in technological innovations.

Feedback Loop

A two-way relationship is illustrated as the feedback loop in Figure 2. In the feedback loop, as independent variable, firm innovation influences the actors' cognitive structures and social capital. Managers' mental models change through adaptation and learning. As managers receive feedback about organizational performance, they correct their mental models to keep up with the environment. Organization can learn from its own experience and borrow experience from others (Huff, 1982). A firm's performance triggers the adaptive learning process (Greve, 1998; Lant & Hewlin, 2002; Lant & Hurley, 1999; Lant, Milliken, & Batra, 1992). Organizational change is based on interpretations of experience, and performance feedback is used routinely to determine whether past performance is satisfactory and to detect problems (Cyert & March, 1963; Levitt et al., 1988). An increase in exploitative searches will change the routines, information flow, and reference points in the different direction. To refine and extend the existing competencies, a flexible and chaotic organizational routine has to become better ordered.

Information flow becomes more top-down rather than bottom-up and firms are more likely to look to their competitors with superior capabilities of exploiting the existing innovations.

During this feedback process, actors' cognitive complexity is reinforced by increasingly exploratory searches because managers or entrepreneurs are forced to diversify their points of view and establish causal relationships between more *diverse* factors. An increase in exploratory searches will change the established routines and information flow in a firm. A rigid organizational routine becomes more flexible, and the decision-making authority becomes more decentralized. More information is generated from the bottom of a firm, and information flow is more diversified. Meanwhile, the firm will change its reference points to more innovative firms or institutions.

Proposition 5a: A firm's exploratory search in technological innovations is associated positively with the actors' cognitive complexity.

Furthermore, actors' cognitive centrality is reinforced by the increasing exploratory searches because managers or entrepreneurs are becoming more efficient to differentiate the core factors from the peripheral factors in exploring new productive opportunities.

Proposition 5b: A firm's exploratory search in technological innovations is associated positively with the actors' cognitive centrality.

Simultaneously, a firm's social network is changing with different innovation output.

With more exploratory search activities, managers or entrepreneurs adapt to the new requirement by building business ties with diverse businesses. The positive feedback will reinforce this tendency of building a diverse social network. Meanwhile, with more exploitative search activities, firms are more likely to focus on their existing

competencies and examine the current business network for information and knowledge.

Positive performance will also reinforce this tendency to build a dense social network.

Proposition 6a: A firm's exploitative search in technological innovations is associated positively with the density of its social capital.

Proposition 6b: A firm's exploratory search in technological innovations is associated positively with the diversity of its social capital.

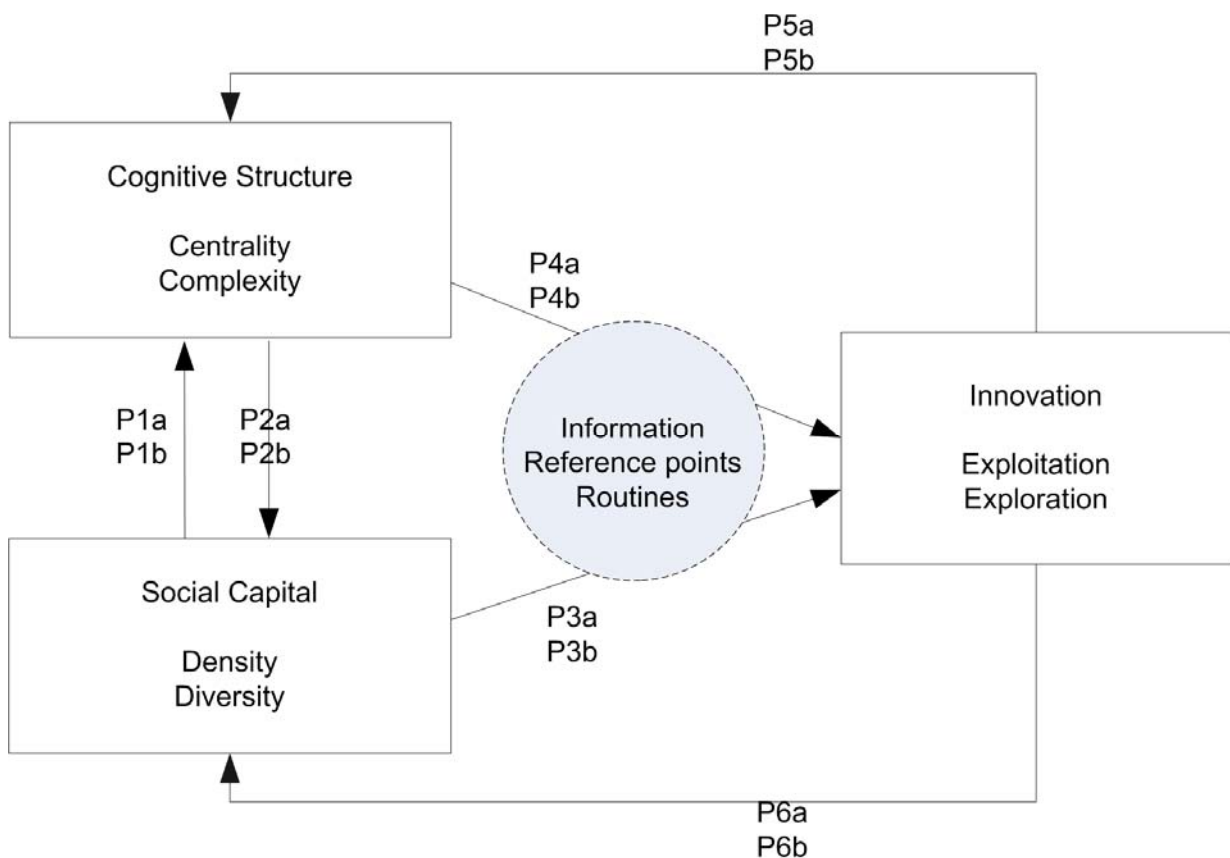


Figure 5 Social Capital, Cognitions and Innovation: A Theoretical Model

A Dynamic Process

The structure of social networks co-evolves with the complexity and centrality of the actor; consequently, the benefits of homogeneous and diverse networks are subject to evolutionary changes. An actor's subjective perception in discovering the opportunities in these networks drives the formation and performance of either diverse or homogeneous network structures. Reversely, the structure of social networks affects the cognitive structures of the embedded actors. This is a dynamic, self-reinforcing process.

Actors actively discover the benefits of different networks and take actions that eventually transform existing network relations. During the initial periods, greater complexity creates greater network diversity and enables timely identification of innovation opportunities. However, other firms can imitate the innovations of a diverse network. Following this initial stage, actors favor the social capital benefits of network homogeneity because their imitation and revision behaviors improve resource efficiencies.

The exploration of diverse networks increases trial and error experimentation costs.

Homogeneous networks erode the basis for competitive differentiation because they promote homogeneous behaviors. Firms must respond to competition by being alert to the social capital benefits of diverse networks. This exploration versus exploitation dilemma is also represented in the selection of social networks at different stages of market development.

Through a venture's life cycle, firms form a 'balanced network' (Uzzi, 1997), simultaneously exploiting the benefits of network homogeneity and network diversity. In a relatively homogeneous network, actors coordinate the learning experiences of their group to enhance the efficiency of their resource choices. Meanwhile, they are

establishing boundary spanning network relationships to benefit from innovations. In constant innovations, actors can differentiate themselves from the increasing competitive conditions of network homogeneity. Competitive advantage comes from this balance of flexibility and efficiency (Gargiulo et al., 2000). Embedded actors need to define an “optimal balance” of these network relationships (Uzzi, 1997). A sustainable innovation requires the appropriate balance between exploiting previous products and exploring novel products (Benner & Tushman, 2003; March, 1991). Exploitation leads to improved performance and efficiency; however, a long-term competitive advantage depends on the novelty of exploration to escape from a sub-optimal competitive position (March, 1991). Rather than over-dependence on one type of network structure, actors establish a dynamic balanced network to explore innovative opportunities and exploit current innovations.

Proposition 7a: Through a firm’s life cycle, a firm tends to have a balanced network; which means there is an inverted-U curve between network density and exploitation, and there is an inverted-U curve between network diversity and exploration.

Proposition 7b: Through a firm’s life cycle, managers or entrepreneurs tend to form balanced cognitions; which means there is an inverted-U curve between cognitive centrality and exploration, and there is an inverted-U curve between cognitive complexity and exploration.

Discussion

This chapter presents fourteen propositions linking social capital (density and diversity), cognitive structures (centrality and complexity), and technological innovation (exploitation and exploration). This social-cognitive view integrates social network

studies and managerial cognition studies to investigate the business phenomenon of firm innovation. This proposed theoretical model describes the mechanisms by which social capital and cognitions influence innovation process. These propositions have important implications for managerial practice, especially in market domains where firm performance is strongly driven by innovation success.

Chapter IV SOCIAL CAPITAL, MANAGERIAL COGNITIONS AND INNOVATION: EMPIRICAL EVIDENCE IN A HIGH-TECHNOLOGY INDUSTRY

In this study, I empirically test the proposed model in a high-technology industry - the U.S. semiconductor industry. The hypotheses are presented first, followed by the methodology and variables description, as well as the data analysis and discussion.

Hypotheses Development

Social capital's effect on cognitive structure

From the distributed cognition perspective, external forces shape the embedded actor's motives and perceptions because the individual outsource the cognitive tasks to the outside objects and related people. Cognitive similarity results not only from the similar beliefs but also from the same social relationships to filter information and simplify decision-making. Business relationships and local community provide the fact premises and value premises upon which the managers rely in decision-making. In the high technology industries, their business ties are constantly changing to respond to the new environment. A firm's social capital is a decision-making entity rather than the embedded managers.

In a homogeneous network, managers share and learn similar information and knowledge. However, in a diverse network, managers outsource cognitive tasks to diverse business contacts; consequently, diverse network promotes the embedded managers' cognitive complexity. Furthermore, this information diversity influences the hierarchy property of cognition – cognitive centrality. To make an efficient and effective business decision,

actors develop a deeper understanding of technological innovations. They are able to differentiate the key factors from the peripheral factors.

Hypothesis 1: The diversity of a firm's social capital is associated positively with its top management team's cognitive centrality.

Social capital and cognitive structure's effects on technological innovation

Determinants of firm innovative activities can be attributed to external and internal factors. Next I developed hypotheses on the effects of external social capital and internal managerial cognitions on firm innovation, controlling for other potential factors. Social capital refers to the collective inter-organizational alliances of a firm. Managerial cognitions refer to the collective cognitions of a firm's top management team.

This study focuses on technological innovation which is differentiated into exploitative innovations and exploratory innovations. As discussed before, exploratory innovation and exploitative innovation are distinct constructs (Chapter II and III).

In high-technology industries, alliance activity has been most intensive in the recent past (Hagedoorn, 1993). Technology firms collaborate with each other to bring together complementary assets owned by different organizations (Nohria & Garcia-Pont, 1991). Social ties provide access to information possessed by one's contacts (Burt, 1992).

Strategic coalitions can convey access to the resources or know-how possess by one's partners. In the semiconductor industry, many horizontal alliances have been established to require device or manufacturing technology from their strategic partners (Stuart, 2000).

Inter-organizational alliances and joint ventures have significant impacts on firm-level outcomes such as the performance of startups and new firms (Baum et al., 2000; Stuart, 2000), firm valuations (Das, Sen, & Sengupta, 1998), organizational learning (Anand &

Khanna, 2000; Kale et al., 2000; Kraatz, 1998; Oliver, 2001), and innovation (Powell et al., 1996; Shan et al., 1994). According to the learning perspective, joint ventures and alliances provide access to information and knowledge resources that are difficult to obtain by other means and which improve firm performance and innovation (Kale et al., 2000; Kogut, 2000; Oliver, 2001; Powell et al., 1996; Rindfleisch & Moorman, 2001; Rosenkopf et al., 2001). Inter-firm network structures affect learning and innovation (Kogut, 2000; Oliver, 2001; Powell et al., 1996). These ideas are identical to the information side of the social capital literature (Burt, 2003).

A firm's social capital has a significant influence on technological innovation by providing information and reference points as well as by influencing the organizational routines. A firm's business relations provide information about the product and supply markets, technical information and information about changes in the external environment. Cohesive and frequent social interactions with similar firms provide homogeneous information to the firm. This high density of social capital reduces uncertainty through trust, and produces homogenous and clustering behaviors. However, this homogeneity may affect a firm's ability to innovate beyond a given technological trajectory due to the cognitive dependence on the information provided by the social capital. On the contrary, a firm with more diverse business ties is more likely to access new information, ideas and resources. New ideas and knowledge can be accessed and recombined from non-redundant sources, diverse networks provide benefits of creativity and innovation (Granovetter, 1983; Perry-Smith et al., 2003; Reagans et al., 2001). Firms benefit from a diverse social capital because of diverse information connections.

Meanwhile, a firm's business relations provide a context in which the managers can observe and emulate similar firms. With dense ties with similar firms, the firm tends to imitate these peers' strategies and focus on increasing efficiencies in resource use. These similar firms serve as reference points informing the setting of aspiration level and providing examples to emulate (Cyert et al., 1963). With business ties with diverse organizations, the firm can improve its innovative abilities by observing very different firms.

Moreover, the business relations provide organizational routines that can be directly incorporated into the firm. A standard business routine is more likely to emerge in a homogeneous business network, and members are more inclined to adopt it. Meanwhile, in a dense social network, managers focus on the mutual coordination and specialization consequences of the organizational routines. Since the executives interact with familiar managers, the firms tend to have stable routines because of the lack of external shocks. However, stable routines play a role in firms' inability to respond appropriately to technological change (Christensen & Bower, 1996; Henderson et al., 1990). As routines become increasingly coordinated, firms become resistant to change and can not respond adequately to environmental changes. The embedded firm's innovations are more likely to be incremental as it learns through repetition of routines (Levitt et al., 1988).

Hypothesis 2a: The diversity of a firm's social capital is associated negatively with its exploitative search in technological innovations.

Hypothesis 2b: The diversity of a firm's social capital is associated positively with its exploratory search in technological innovations.

Knowledge and cognitions are important in the innovation process. Organizations and technologies are socially constructed by the people that describe and interpret organizations and technologies. The cognitive views that the principal actors have of the technology determine the emergent organizational structure. A technical system is operated by different social systems such that ultimately the design of work depends on human choices about how best to optimize the fit between the technical and social systems (Thompson, 1967). Human understandings and mental models influence the ways in which the technologies function. There is no objective “real” organization or technology independent of the cognitions of the people involved (Weick, 1979). New technologies are equivocal, and they “require ongoing structuring and sense-making if they are to be managed” (Weick, 1990: 2). The same technology can be interpreted by different actors with different cognitive frameworks. Cognitions of principal actors are crucial in mediating the relations between technology and organization structure (Lowstedt, 1985).

Managerial cognitions mediate the relation between social capital and technological innovation by influencing the process of collecting information, finding reference points and building organizational routines. Top management teams collectively construct knowledge structures consisting of organized knowledge about an information environment that enables interpretation and action in that environment. Managers create a model of the world in their minds and use this model to simplify the complex environment. Since few firms can have expertise in producing domain knowledge, processing practical knowledge and customer knowledge, it is increasingly critical to collaborate with customers, suppliers and research institutes. However, managers with

more complex cognitive structures are more alert to different types of information and other external influences. They are paying more attention to the different reference points, and are less constrained by the stable routines. Furthermore, managers with more cognitive centrality can assimilate different information flows more efficiently. Their ability of differentiating core factors from peripheral factors enables these managers to use different reference companies for different factors. This information-processing efficiency enhances their ability of noticing the environmental changes and being less constrained by the existing organizational routines.

Hypothesis 3a: Top management team's cognitive centrality is associated negatively with the firm's exploitative search in technological innovations.

Hypothesis 3b: Top management team's cognitive centrality is associated positively with the firm's exploratory search in technological innovations.

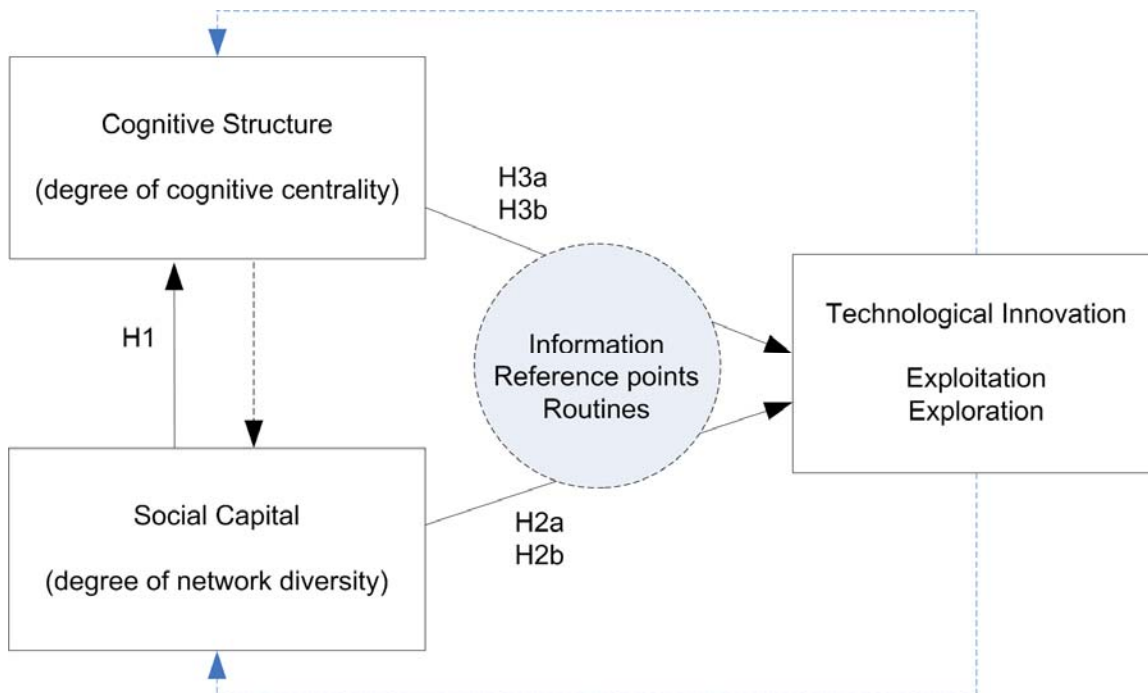


Figure 6 Hypotheses in the First Empirical Study

Setting and Sample

I tested these hypotheses with a longitudinal study of firms in the U.S. semiconductor industry over the period 1991 to 1998. I did this empirical test in the context of a single industry to control for the industry effects. I chose the U.S. semiconductor industry for the following reasons: first, the semiconductor industry has been driven by innovation. The surest path to commercial success has been to develop new technologies (Tilton, 1971; Wilson, Ashton, & Egan, 1980). Because of the priority of technological innovation in this industry, it is an appropriate context to investigate the effects of social ties and top management team’s cognitions on firm innovation. Second, companies in the

semiconductor industry have formed many strategic alliances (Hagedoorn (Hagedoorn, 1993). A sufficient number of alliances in this industry allows for a large sample study of the effects of social ties on firm innovations. Third, firms in this industry routinely patent their inventions, which makes it practical to operationalize a number of the variables using patent data. Finally, the managers of this industry view innovation as a priority. Analyzing their letters to shareholders reveals their cognitive characteristics. Meanwhile, since I can obtain the most complete data for U.S. firms, I decided to focus on U.S.-headquartered firms in this empirical study; at the same time this can avoid the potential administrative biases in cross-country comparisons. The sample I have analyzed included 31 public firms in the American semiconductor industry that were U.S. owned and headquartered in U.S. Table 1 lists these firms.

Chapter IV Table 1: List of Semiconductor Firms Covered in the Analysis 1991-1998

Intel Corp	Standard Microsystems Corp.
Texas Instruments Inc.	Siliconix Inc.
Advanced Micro Devices	PMC-Sierra Inc.
Micron Technology Inc.	Exar Corp.
National Semiconductor Corp	Triquint Semiconductor Inc.
LSI Logic Corp	Integrated Circuit Systems
Analog Devices	IMP Inc.
Integrated Device Technology Inc.	Micrel Inc.
Cypress Semiconductor Corp	Supertex Inc.
XILINX Inc.	Catalyst Semiconductor Inc.
Altera Corp.	Semtech Corp.
International Rectifier Corp.	Sigma Designs Inc.
Linear Technology Corp.	Energy Conversion Devices
Zilog Inc.	Hei Inc.
Lattice Semiconductor Corp.	Advanced Photonix Inc.
Alliance Semiconductor Corp.	

Data and Variables

Dependent variable – Technological Innovation

The six hypotheses posit relationships between a firm's social ties and top management team's cognitions on firm innovation activities, measured either as a rate of innovation or as the exploitative or exploratory search. To test the hypotheses, it is necessary to derive measures of the innovativeness.

Measures of search activities in technological innovation are developed using data from the U.S. Patent and Trademark Office (USPTO). Patents are only awarded to novel, non-obvious designs that represent advancements over existing technology. Firms in the semiconductor industry actively file for patents because of the increased strength of U.S. intellectual property protection (Rivette, 1993). As a useful measure of innovative activity (Griliches, Pakes, & Hall, 1987; Podolny & Stuart, 1995), the data on patent activity was constructed using information from the National Bureau of Economic Research (NBER www.nber.org/patents) patent database. This database contains information about the assignee (the company that owns the patent), the three-digit patent classification, indicating the technology area in which the patent is granted, and the technological antecedents of the invention, indicated by references to prior patents. I have selected patents within the technology classifications that represented semiconductor. The first measure of firm innovation is number of semiconductor patents issued to the firm every year during the period between 1991 and 1998. The patent classes and their definitions included in this study are listed in Appendix A. Considering there may be arbitrarily long lags between filing and approval dates for patents (Ahuja, 2000a), patents

are recorded by filing dates, instead of approval dates, to pinpoint the patent measure to the time when firm innovation activities were actually undertaken. Although the propensity for patenting varies considerably across industries (Gockburn & Griliches, 1987), this was not a problem in this study because I focused on one industry. Patents are reliable as innovation measures because the semiconductor firms actively file for patents (Stuart, 2000).

In addition, innovativeness measures for the sampled firms have been constructed using the patent citation data. USPTO requires every patent applicant to list citations to all previously-granted patents, which means that patent applicants must identify and acknowledge the existing, patented inventions that are technologically nearest to their inventions. The patent examiner verifies that the list of references in the patent application is complete. A very high correlation exists between the number of citations received by a set of patents and the rankings by technical experts in the relevant field of the importance of these inventions (Albert, Avery, Narin, & McAllister, 1991). The patent citation data is a reliable source to obtain the innovativeness measures.

These measures of exploitative and exploratory search behaviors are based on the extent to which a firm's innovation efforts were anchored in its existing knowledge. I assumed that the extent to which a firm was drawing on its existing knowledge was reflected in the extent to which it cited patents that it had cited in earlier patenting efforts. These measures further improve on prior research by focusing not only on self-citations but also on repeat citations as measures of exploitative search. These measures provide better insight into the extent to which a firm's innovation builds upon or exploits familiar knowledge it has used in prior patenting efforts (Benner et al., 2002; Katila et al., 2002).

The variable *search depth* describes accumulation of search experience with the same knowledge elements. It is measured as the average number of times a firm repeatedly used the citations in the patents it applied for (Katila et al., 2002). In high-technology companies, knowledge depreciates sharply, losing significant value within approximately five years (Argote, 1999). This variable calculates the number of times that each citation in year t-1 was repeatedly used during the past five years.

$$Depth_{it-1} = \frac{\sum_{y=t-6}^{t-2} repetitioncount_{iy}}{totalcitations_{it-1}}$$

The variable *search scope* is the proportion of previously unused citations in a firm's focal year's list of citations (Katila et al., 2002). It calculates the share of citations in a focal year's citations that could not be found in the previous five years' list of patents and citations by that firm.

$$Scope_{it-1} = \frac{newcitations_{it-1}}{totalcitations_{it-1}}$$

The assumption in this approach is that exploratory activities require distant search and a departure from the firm's current skills and capabilities. The more exploratory an innovation is, the more a firm departs from knowledge used in prior innovation efforts. Conversely, the more exploitative an innovation is, the more deeply a firm is anchored in its existing knowledge (Benner et al., 2002; Katila et al., 2002).

Independent variables

Social Capital.

I recorded all publicly-reported alliances formed between each semiconductor company and their business partners since the founding of the semiconductor company. Key-word

searches were conducted to identify the relevant articles in the Factiva database. The main sources for the alliance data included Electronic Engineering Times, Infotrak, Business Wire, Electronic News, PR Newswire, and international publications. The data, consisting of more than 4700 dyadic ties, include the following nine types of collaborative relationships: joint product development agreements (horizontal), joint venture and other equity alliances, technology exchanges, (cross) licensing, second source marketing agreement and distribution, joint product development agreements (vertical), research and development agreement with national labs and academic institutes, manufacturing and supply agreements, as well as other agreements excluded above. I used the Entropy index (Hoskisson, Hill, & Kim, 1993; Jacquemin & Berry, 1979; Palepu, 1985) to measure the diversity of social capital. This index measures the degree of dispersion of dyadic ties in various collaborative relationship types by multiplying a weight variable $\ln(1/p_i)$. The entropy index was originally developed in information theory and traditionally used by ecologists (Frenken, 2004).

$$\text{Entropy Measure} = \sum_i [p_i \times \ln(1/p_i)]$$

where P_i is defined as the proportion of type i 's dyadic ties in all collaborative relationships and $\ln(1/p_i)$ is the weight for each type i .

Managerial cognitions.

Obtaining valid measures of senior management cognitive structures is difficult because retrospective interviews and memories are often incomplete, misinterpreted, or mistakenly reported because of the outcomes later achieved (Babbie, 1992; Bettman and

Weitz, 1983; Bazerman, 1986; Hodgkinson, 1997; Kiesler and Sproull, 1982). To deal with these problems, this study utilized computer-assisted content analysis of archival data in presidents' letters to shareholders. In these letters, senior managers discuss issues or themes important to the company. Analyzing these themes can partially measure the company-level mental models of senior managers. Annual reports, interviews or questionnaires are the raw data used to map cognitive mental models, and these sources are subject to distortion (Bazerman, 1986; Bettman & Weitz, 1983; Fiol, 1995). However, previous research supported the use of narratives to reveal the mental models (Barr, Stimpert, & Huff, 1992; Fiol, 1995; Jackson, 2000; Swales, 1988). There is also evidence that annual report text assertions about firm innovativeness are valid (Michalisin, 2001). To capture mental models, I used a multistage design based on computer-assisted content analysis (Osborne, Stubbart, & Ramaprasad, 2001). Appendix B describes this systematic multi-step process which was used to measure the senior management cognitions. To find the common themes in the presidents' letters, first I collected 180 annual reports from the semiconductor industry's top American companies listed in Table 1. Most reports were obtained from the Lexis/Nexis electronic database, and the others were solicited directly from the companies and scanned into electronic files.⁵ Conversion accuracy was manually checked, and all the data were cleaned, indexed and labeled. The next step is to identify the common themes by common factor analysis. Using the VBPro program (Miller, 1995), I processed the presidents' letters of each year and identified 40~50 most frequent non-structural words. Structural words such as articles, prepositions, conjunctions, and auxiliary verbs were eliminated. Instead of the classic content analysis

⁵ Finally, approximately 27.4% of the letters were missing. The majority of these were smaller firms.

(Babbie, 1992; Holsti, 1968; Kassirjian, 1977), common factor analysis was conducted to find meaningful themes. This nondependence method allows the data to speak, thereby greatly reducing the research bias (Jackson, 2000; Osborne et al., 2001). Using SPSS 11.50 (SPSS, 2002), I conducted common factor analysis that was iterated on progressively smaller sets of the most frequent words by using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (Hair, Anderson, Tatham, & Black, 1992). Words that were below the minimum standard set out by the Kaiser-Rice Scale (Stewart, 1981) were removed. After a VARIMAX rotation, the result was a set of five or six themes for each year. Each theme consisted of two to seven words with high factor loadings.⁶ I verified the validity of the themes by constantly returning to the indexed text of the presidents' letters. The same procedure was completed for each of the eight years. Table 2 shows the themes and their loadings for the year of 1992.

Chapter IV Table 2: Themes discovered by common factor analysis (Year 1992)

Strategy	Management	Marketing	Operations	Innovation
Competition (0.81) ^a	Business (0.74)	Customer(s) (0.70)	Operations (0.71)	Introduction (0.87)
Development (0.86)	Employee(s) (0.78)	Investment(s) (0.73)	Profitability (0.86)	Technology (0.53)
New (0.78)	Opportunities (0.66)	Team (0.86)	Restructuring (0.75)	Patent(s) (0.86)
Niche (0.94)	People (0.90)			Innovation(s) (0.82)
Production (0.87)	Future (0.82)			
Strategy (0.88)				

^a Factor loadings after a VARIMAX rotation

⁶ This method of identifying common themes is built on the previous literature. For example, Osborne, J. D., Stubbart, C. I., & Ramaprasad, A. 2001. Strategic groups and competitive enactment: A study of dynamic relationships between mental models and performance. *Strategic Management Journal*, 22(5): 435.

In the third step, based on the assumption that a word is indicative of the perceptions or thoughts of senior management to the degree that it has a relatively high frequency in the letter to shareholders, I used the Hirschman-Herfindahl index (HHI) to measure the cognitive centrality of top management team. The Herfindahl measure captures the degree of centralization of words in various themes by considering the proportion of words accounted for by each theme.

$$HHI = \sum_i p_i^2$$

where P_i is defined as the proportion of theme i 's words in all themes.

Control variables

Four control variables (*firm size*, *R&D investment*, *patenting*, and *firm dummies*) account for stable differences between firms, such as firm size, and within-firm variation, such as patenting activities in each year.

Firm size is measured by the number of the employees working for a firm in a specific year. *R&D investment* is measured by the proportion of a firm's research and development expenditure in its annual sales. Firm size and R&D expenditure have been shown to be significant factors in technological innovation (Acs & Audretsch, 1987; Cohen & Klepper, 1996; Cohen & Levinthal, 1990; Ettlé & Rubenstein, 1987; Gregory, Noel, & William, 2002; Mazzucato, 2000; McNulty, 1974; Scherer, 1965; Yin & Zuscovitch, 1998). Data of firm size and R&D investment were obtained from the Compustat database.

The *patenting* variable measures changes in firms' patent applications from year to year. I used a two-year rolling average to measure this within-firm variation (Benner et al., 2002). Fourth and finally, I control for factors that differ across firms but that are

relatively stable over time within firms with firm fixed effects. This dummy variable controls for any unobserved heterogeneity that is responsible for observed differences in social capital, managerial cognitions and innovation.

Analysis and Findings

I utilized a cross-sectional, time series (panel) data design with fixed (firm) effects controls to analyze data. This design can eliminate many alternative explanations for observed changes in innovation and minimizes the risk of omitted-variable bias. This design is particularly useful to control for the collective effect of the potential control variables (Hsiao, 1986).

The model I used to test hypotheses 1a and 2a is represented by the following equation:

$$\log y_{it} = x_{it}\beta + \mu_i + \varepsilon_{it}$$

where y_{it} is the observed count of firm i's patent applications at year t; x_{it} is a vector of characteristics of firm i at year t, including the independent variables and control variables; μ_i is a firm i effect, which is treated as fixed to limit the variation used in the analysis to within-firm estimates; and ε_{it} is an error term.

The model I used to test hypotheses 1b, 1c, and 2b, 2c is represented by the following equation:

$$R_{it} = x_{i,t}\beta + \mu_i + \varepsilon_{it}$$

where R_{it} is the search depth or search scope of firm i at year t; x_{it} is a vector of characteristics of firm i at year t, including the independent variables and control variables; μ_i is a firm i effect, which is treated as fixed to limit the variation used in the analysis to within-firm estimates; and ε_{it} is an error term.

Table 3 presents a summary of the constructs, and corresponding proxies. Table 4 presents the descriptive statistics and correlation matrix of all the variables. It is noteworthy that exploitation and exploration is negatively correlated. Although this correlation is significant, which indicates that the exploitative activities drive out exploratory search activities (Benner et al., 2002), these two variables are not perfectly correlated. In other words, they are not on the same continuum. In this study, I tested the effects of social capital diversity and cognitive centrality on each of them.

Chapter IV Table 3: Summary of Constructs, and Proxies

Constructs	Proxies
Cognitive centrality	Cognition Hirschman-Herfindahl index
Exploitative search	Search depth
Exploratory search	Search scope
Social capital diversity	Social capital Entropy index
Firm size	Number of employees
R&D investment	Proportion of R&D expenditure in annual sales
Patenting	Two-year rolling average of patent applications

Chapter IV Table 4: Pearson Correlations ^a

	Mean	s.d.	1	2	3	4	5	6	7
1 Cognitive Centrality	0.398	0.142							
2 Exploitation	0.321	1.003	.217**						
3 Exploration	0.772	0.234	-.102	-.472***					
4 Social capital diversity	0.998	0.584	-.021	.158*	-.292***				
5 Firm size	5326.992	12535.457	-.071	.031	-.153*	.458***			
6 R&D investment	0.138	0.072	.137	-.083	.141†	.048	-.148*		
7 Patenting	44.919	73.302	-.083	.075	-.249***	.461***	.750***	-.153*	

^a 147 < N < 248

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Chapter IV Table 5: Pooled cross-sectional time series with fixed (firm) effects controls:

Effects of Social Capital Diversity on Cognitive Centrality ^a

	Model 1	Model 2	Model 3
(Constant)	.322*** (.039)	.124 (.125)	-.075 (.135)
Firm size	-1.126E-06 (.000)	6.842E-07 (.000)	1.833E-06 (.000)
R&D investment	.693* (.269)	1.230* (.522)	1.506** (.505)
Patenting	.000 (.000)	.001† (.000)	.001 (.000)
Firm dummies		Dummies 1-31	Dummies 1-31
Social capital diversity			.202** (.063)
R ²	.063	.301	.370
F	2.645†	1.432	1.865*

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses. Firm dummies were included but are not shown. N=122

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Table 5, 6, and 7 present the results from the regression analysis with fixed effects.

Models in Table 5 include firm size, R&D investment, patenting activities, and firm dummies as control variables. In Model 3, the social capital diversity has a positive and significant effect on the cognitive centrality. Nine firm dummies are also significant. This result supports Hypothesis 1 – A firm’s social capital diversity is associated positively with the top management team’s cognitive centrality.

Chapter IV Table 6: Pooled cross-sectional time series with fixed effects controls: Effects of Social Capital Diversity and Cognitive Centrality on *Search Depth (exploitation)*^a

	Model 1	Model 2	Model 3	Model 4	Model 5
(Constant)	.569*	.433	-1.103	.102	-1.205†
	(.232)	(.684)	(.717)	(.681)	(.713)
Firm size	-5.032E-06	3.498E-06	8.286E-06	-1.312E-06	4.738E-06
	(.000)	(.000)	(.000)	(.000)	(.000)
R&D investment	-1.663	-2.071	-2.339	-3.714	-3.444
	(1.480)	(2.536)	(2.396)	(2.558)	(2.463)
Patenting	.001	.001	.000	.001	.000
	(.002)	(.003)	(.002)	(.003)	(.002)
Firm dummies		Dummies 1-31	Dummies 1-31	Dummies 1-31	Dummies 1-31
Social capital diversity			2.320***		2.167***
			(.477)		(.481)
Cognitive centrality				1.893*	1.230†
				(.734)	(.727)
R ²	.012	.215	.354	.257	.371
F	.572	1.104	2.039**	1.340	2.100**

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses. Firm dummies were included but are not shown. N=138

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Models in Table 6 include firm size, R&D investment, patenting activities, and firm dummies as control variables. In Model 3 and 5, the social capital diversity has a positive and significant effect on the firm's search depth. Nine firm dummies are significant in Model 3, and eight firm dummies are significant in Model 5. In Model 4, the cognitive centrality has a positive and significant effect on the firm's search depth. One firm

dummy is also significant. However, the F test of model 4 is not significant, which means that I cannot claim this significant relationship is valid. The finding is that the diversity of a firm's social capital is associated positively with its exploitative searches.

Chapter IV Table 7: Pooled cross-sectional time series with fixed effects controls: Effects of Social Capital Diversity and Cognitive Centrality on *Search Scope (exploration)*^a

	Model 1	Model 2	Model 3	Model 4	Model 5
(Constant)	.691*** (.046)	.962*** (.122)	1.065*** (.132)	.993*** (.124)	1.075*** (.132)
Firm size	2.397E-06 (.000)	-4.722E-06 (.000)	-4.982E-06 (.000)	-4.269E-06 (.000)	-4.632E-06 (.000)
R&D investment	.507† (.295)	-.135 (.453)	-.073 (.441)	.020 (.466)	.036 (.457)
Patenting	-.001* (.000)	-.001† (.000)	-.001 (.000)	-.001† (.000)	-.001 (.000)
Firm dummies		Dummies 1-31	Dummies 1-31	Dummies 1-31	Dummies 1-31
Social capital diversity			-.171† (.088)		-.156† (.089)
Cognitive centrality				-.178 (.134)	-.121 (.135)
R ²	.067	.406	.429	.415	.434
F	3.412*	2.759***	2.803***	2.744***	2.732***

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses.

Firm dummies were included but are not shown. N=138

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Models in Table 7 include firm size, R&D investment, patenting activities, and firm dummies as control variables. In Model 3 and 5, the social capital diversity has a negative and marginally significant effect on the firm's search scope. In Model 3 and 5, four firm dummies are also significant. In Model 4 and 5, cognitive centrality has no significant effect on the firm's search scope. In Model 4, five firm dummies are significant. The

finding is that the diversity of a firm's social capital is associated negatively with its exploratory searches.

Discussion

This chapter presents the first empirical study of the proposed theoretical model. First I derived seven firm-level hypotheses linking social capital diversity, cognitive centrality and technological innovations. The analysis results of 31 U.S. semiconductor firms revealed the significant effects of social capital diversity on top management team's cognitive centrality, exploitative search, and exploratory search. Hypothesis 1 is supported – A firm's social capital diversity is associated positively with its top management team's cognitive centrality. However, social capital diversity is associated negatively with exploitation. This finding is opposite to Hypothesis 2a. The possible explanation is that some established semiconductor firms ally actively with their potential customers to exploit their existing skills and capabilities, whereas new entrants focus their networking activities on certain type of partners to explore new technological domains. Although this is beyond the scope of this study, future research could address this issue and analyze the partners of inter-firm alliances.

Meanwhile, the effect of social capital diversity is weaker for exploratory activities. The possible reason is that some semiconductor firms establish relatively independent subsidiaries or business divisions to develop break-through innovations. These internal new ventures attempt to conduct more exploratory searches in technological innovations. Their patenting activities moderated the effects of social capital on the exploratory search. To investigate these effects more precisely, a solution could be using the business unit as

the level of analysis, instead of the firm. Although this is beyond the scope of this study, it could be a direction for future research.

This study did not find any significant effect of the top management team's cognitive structure on the firm's search activities in technological innovation. I used a multi-stage computer-assisted content analysis of president's letter to shareholders to obtain the measure of top management team's cognitive structures. Approximately 27.4% of the letters were missing, particularly for smaller firms. These missing data could influence the analysis results to some extent. Furthermore, analyzing public letters to shareholders has limitations in measuring the top management team's cognitive structures. During the process of cognitive structures influencing organizational actions, the other unobserved factors, in addition to the control variables used in this study, may play significant roles. This measure needs further refinement and improvement.

Chapter V SOCIAL CAPITAL, ENTREPRENEURIAL COGNITIONS AND NEW

VENTURE INNOVATION: A SURVEY OF TECHNOLOGY STARTUPS

In this study, I have investigated the effects of social capital and entrepreneurial cognitions on new venture innovation in the setting of technology startups.

Entrepreneurial firms are risk taking, proactive and innovative (Barringer & Bluedorn, 1999), and the entrepreneur plays a critical role in the new venture success (Hall & Hofer, 1993; Herron, 1990; Shane et al., 2000; Stuart & Abetti, 1990) as the creator of new enterprise (Low & MacMillian, 1988; Rumelt, 1987; Schumpeter, 1934).

Entrepreneurship arises from the actions of particular persons; understanding why and how these persons act as they do is essential to comprehending the entire entrepreneurship process.

In the following sections, I present the hypotheses development, followed by research procedures, operationalizations of variables, and the data analysis, and ended with the discussion.

Hypotheses Development

Social capital's effect on cognitive structure

Entrepreneurs of technology startups incessantly network with specialized, diverse entities including venture capitalists, knowledge professionals, research institutes, service infrastructure, and customers. An entrepreneur relies on their social and business relations to obtain information, knowledge and resources. This social network influences the cognitive structures of the embedded entrepreneur.

Cognitive structures are differentiated along two dimensions: centrality and complexity (Chapter III Figure 4). Complexity reflects the actors' capability of information processing. An actor with a more complex mental model is able to collect more information from the environment and process the information. In complex situations, the more complex the cognitive structure is, the more accurate the perception is, and the more effective the behavior is (Bartunek, Gordon, & Weathersby, 1983). However, information overload may hinder the actor's ability to make effective decisions. Another dimension of cognitive structure, centrality, reflects the level of focus and hierarchy in an actor's mental model. Through gradual learning over time, actors develop a clear distinction between the core concepts and the peripheral concepts in their mental models (Carley & Palmquist, 1992).

Entrepreneurs with diverse business ties outsource cognitive tasks to various information connections. They collect different information, and learn different knowledge from diverse business ties. A diverse social capital affects positively the entrepreneur's cognitive complexity. Meanwhile, through interaction with different business contacts, the entrepreneur develops a deeper understanding of startup innovation, and is able to differentiate the key factors from other concepts. Consequently, a diverse social capital enhances the entrepreneur's cognitive centrality.

Hypothesis 1a: The diversity of an entrepreneur's social capital is associated positively with their cognitive complexity.

Hypothesis 1b: The diversity of an entrepreneur's social capital is associated positively with their cognitive centrality.

Social capital and cognitive structure's effects on innovation

Innovation is constructed through the interaction between actors of a community. Social relationships have been shown to influence the quality and quantity of innovation (Ahuja, 2000a; Powell et al., 1996; Shan et al., 1994). As a special kind of economic activity, innovation requires very special kinds of informational and coordination mechanisms (Teece, 1992). A new venture's social capital affects its innovation activities by providing information and reference points as well as by influencing the organizational routines.

In the entrepreneurial context, social capital differential refers to the uneven endowment of entrepreneurs with social resources in terms of network structure (Burt, 1983b), relations and contact resources (Bourdieu, 1986; Burt, 1992; Coleman, 1990; Flap, 1991; Lai et al., 1998; Lin, 1982, 2001b). The initial resources of entrepreneurs have been found to have significant impacts upon venture performance (Brush & Chaganti, 1999; Cooper, GimenoGascon, & Woo, 1994; Eisenhardt & Schoonhoven, 1990).

On one hand, entrepreneurs seek information, advice and social support from network alters (Aldrich & Zimmer, 1986; Birley, 1985; Nohria, 1992), control and manage exchange structures through network dyads (Larson, 1992), access financial capital (Shane & Cable, 2002; Uzzi, 1999), and get endorsement from prestigious players to influence perceptions of the quality of their ventures (Stuart et al., 1999). On the other hand, social embeddedness has a negative aspect: tightly controlled relationships reinforce social obligations and expectations that may limit the freedom of economic agents to recognize and exploit new opportunities (Light and Isralowitz 1997; Podolny and Page 1998; Uzzi 1997). Previous relationships may turn into social liabilities that

constrain rent-seeking activities of managers and entrepreneurs, affecting negatively their performance indicators (Bean and Bell-Rose 1999; Gargiulo and Benassi 1999; Portes 1995).

Knowledge about the firms, technologies and managers is embedded in the social setting and being used in the social network. The profitable commercialization of technology requires timely access to complementary assets in a competitive marketplace. On one hand, a dense social capital reduces uncertainty through trust, and produces homogenous and clustering behaviors. However, this homogeneity may affect a firm's ability to innovate beyond a given technological trajectory due to the cognitive dependence on the information provided by the social capital. On the other hand, a new venture with diverse business ties is more likely to access new information, ideas and resources. The diverse information connections enable the embedded actors have a greater capacity to discover new productive opportunities and productive relationships (Burt, 1997; Powell et al., 1996).

Meanwhile, an entrepreneur's business relations provide a context to observe and emulate other firms. In a network, knowledge is held in the networks of practice (Brown & Duguid, 2000). Firms tied together share insights and judgments, as well as develop and circulate knowledge inevitably as part of their practice. Other firms serve as reference points which can inform the setting of aspiration level and provide examples to emulate (Cyert et al., 1963). In a dense network, a new venture tends to imitate similar firms' strategies and focus on increasing efficiencies in resource use. In a diverse network, a new venture can observe very different firms and have more reference points.

Moreover, the business network provides routines that can be directly incorporated into the new venture. A standard business routine is more likely to emerge in a dense business network, and members are more inclined to adopt it. Since the entrepreneurs interact with familiar managers or entrepreneurs, the firms tend to have stable routines because of the lack of external shocks. The embedded firm's innovations are more likely to be incremental as it learns through repetition of routines (Levitt et al., 1988). On the contrary, a flexible business routine is more likely to emerge in a diverse business network because entrepreneurs interact with different managers or entrepreneurs. The embedded new venture tends to innovate more radically as it learns through changing routines.

Hypothesis 2: The diversity of a new venture's social capital is associated positively with its degree of innovativeness.

In the competitive environment, firms encounter substantial strategic discontinuities and unpredictable environmental changes. In this uncertain environment, entrepreneurs create a model of the world in their minds and use this model to simplify the complex environment. Entrepreneurial cognitive structures affect the innovation process by providing information and reference points as well as by influencing the organizational routines.

Entrepreneurs with complex cognitions are more alert to various types of information and other external influences. They are paying more attention to the different reference firms, and are less constrained by the stable routines. Furthermore, entrepreneurs with centralized cognitions are able to deal with diverse information more efficiently. This

information-processing efficiency enables them to use diverse reference firms for different factors. They are also more flexible in changing the organizational routines.

Hypothesis 3a: The entrepreneur’s cognitive complexity is associated positively with the new venture’s degree of innovativeness.

Hypothesis 3b: The entrepreneur’s cognitive centrality is associated positively with the new venture’s degree of innovativeness.

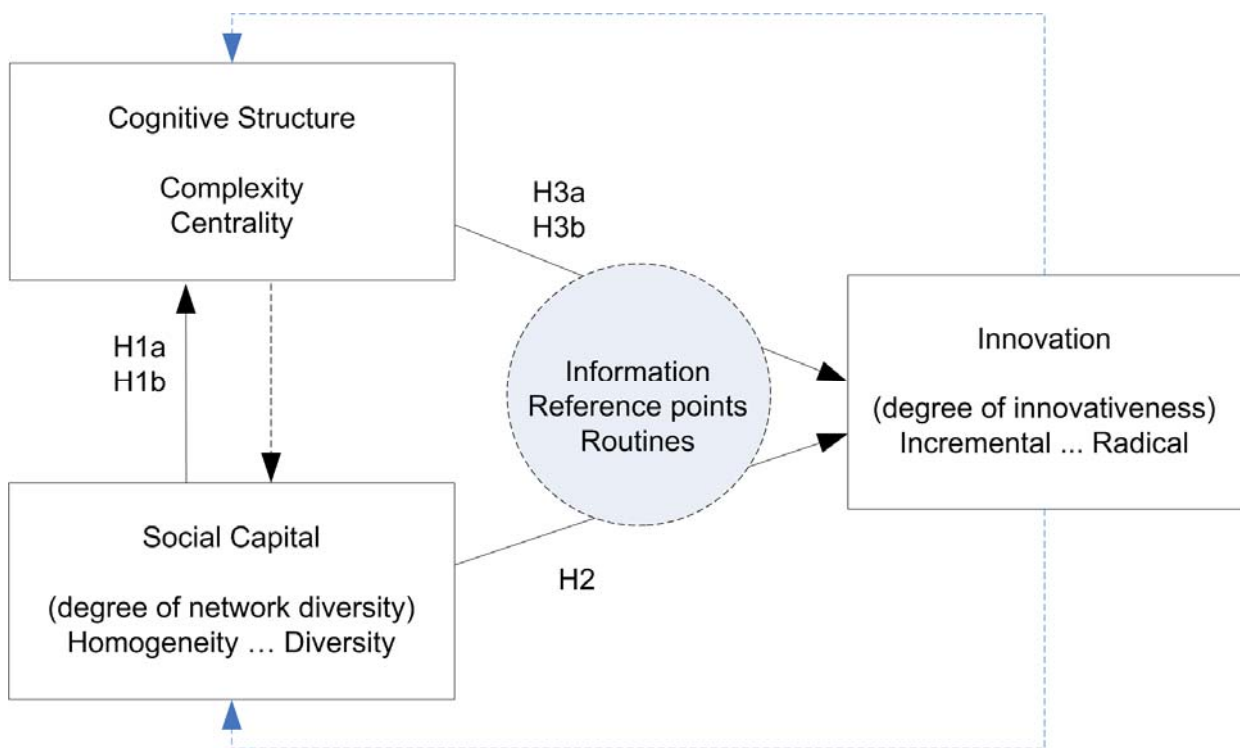


Figure 7 Hypotheses in the Second Empirical Study

Sample and Survey Design

Participants were recruited directly by sending out the paper questionnaires addressing the owner of the firm followed up with telephone calls. Owner’s contact information was

obtained from the 2006 Pennsylvania Manufacturers' register (Pennsylvania Manufacturers Register, 2005) and Virginia Tech Corporate Research Center web site (<http://www.vtcrc.com>). I employed five criteria when I developed the sample. First, I selected new ventures from multiple technology industries to increase the findings' generalizability. These industries are selected based on the U.S. Department of Commerce classifications (Brown & Garten, 1994): Aerospace and defense, Biotechnology, Chemicals, Computer/peripherals, Education/training, Environmental science, Internet/Online services, Materials Science/ Nanotechnology, Pharmaceuticals, Professional/consulting services, Semiconductor/ Microelectronics, Software/applications, Telecommunications/IT. These industries are important for innovativeness and regional competitiveness (Datar, Jordan, Kekre, Rajiv, & Srinivasan, 1997; Yoo, 2003). Second, I restricted the remaining sample to firms 10 years of age or younger in this study. Different age ranges have been used in the previous literature, such as 12 (Covin, Slevin, & Covin, 1990), 8 (McDougall, 1989; Zahra, 1996) , and 6 years (Zahra, Ireland, & Hitt, 2000). By the age of five, many startups have become extinct if they have failed to build strong market positions; meanwhile, older companies (up to the age of 12) have survived the liability of newness but have not become established firms (Bantel, 1998). Given the desire to track the entrepreneur's social network change, and need to include enough samples in the mail survey, I used only firms 10 years of age or younger. Third, the potential sample was required to be an independent business, rather than a subsidiary, a division of another firm, or a unit of a conglomerate. Otherwise, the startup's social capital and innovation is attributed to decisions made by the parent firm rather than the entrepreneur. Fourth, I selected only private firms rather than well-established public

ones. In public-listed firms, the founder(s)' business decisions are greatly influenced by the significant shareholders (Useem, 1996). Fifth and finally, only firms with fewer than 500 employees were allowed to be in the sample. This selection criterion is consistent with the definition of Small Business Administration (Small Business Administration, August 2001).

The questionnaire was in structured form, containing mainly multiple-choice questions. The exact wording of the questionnaire is described in Appendix C.

To encourage participation and valid responses, the introduction script of the questionnaire emphasized the potential benefits of this project to the entrepreneurs themselves. If any respondent request, I would send them an analysis report about comparing his/her cognitions and social capital with those of others as well as their effects on startup innovation. In addition, the survey gave the respondents an opportunity to participate in the gift card sweepstakes. One prize of a \$35 gift card was randomly drawn out of every five *valid* responses.⁷

The same survey was also available online. This web-based survey form is exactly the same as the mail questionnaire. Respondents have the option to fill out the survey online. To control its access and prevent fraudulent data, this web survey contains a password which was printed on a card enclosed in the mail to the participants. I also asked for the actual names of the participants and organizations. They were saved into a separate database from the cognitions, social capital and innovation data to preserve anonymity. The identifications made it possible for me to provide the entrepreneurs with a report

⁷ The gift card sweepstakes did not create any bias in the responses because the possibility of winning a \$35 gift card is nominal for the business owners. 18.6% of the respondents chose not to participate in the

based on their survey responses. The incentive provided to participants – an analysis of their cognitions, business ties and a comparison of their networks and performance to their peers – discouraged them from providing inaccurate responses. Meanwhile, the survey has strived to provide the highest level of convenience for the entrepreneurs. For example, the survey offered the “pull-down menus” whenever possible and automated links to the appropriate questions based on their responses. The integrity of the data was ensured by providing spaces to write in the responses for some of the questions. The “fill-in-the-blank” responses were manually coded and examined.

The online questionnaire as a complement to the mail survey was appropriate for this study because of the following reasons. First, information regarding cognitions and social relations is a deeply personal and sensitive matter, participants are more likely to respond frankly in an impersonal setting. This is especially important because the survey asks the respondents to explore their own cognitions and the strength of their business ties.

Second, the ability to complete web-based surveys at the participants’ convenience is likely to encourage response. The interactive and branching feature of the web survey can also encourage the responses. Third, the web-based survey does not create sampling bias because of the focus on highly computer-literate professionals (Cihan, Bill, & Patrick, 2001; Dillman, 2000; Jake & William, 2003; Jonathan & Jennifer, 1999). Fourth, the cost of deployment and analysis of a web-based survey is substantially lower than that for a telephone or mail survey because of the minimal costs of electronic distribution and because responses are entered directly into a database rather than hand-coded. This method also eliminates potential errors made in the manual entry of survey data.

sweepstakes. T-tests did not reveal any significant difference between this group of respondents and the other willing to participate.

First, two pilot tests were conducted over a period of six months using participants that were not included in the sample. I emailed the solicitation messages with the password to the online survey form to the industry experts. Based on their feedback, I modified most survey items. Next, approximately 700 technology new ventures in Pennsylvania and Virginia were contacted during the period between August 2005 and January 2006. 51 firms could not be reached, in spite of checking their address data. As a result, 649 firms were reached by mail. Among these 649 firms, 39 completed the full 6-page questionnaire, and 51 completed the survey online. Among the 90 respondents that completed the questionnaire, 70 are the founders of their businesses. The final database of 70 firms corresponds to a response rate of 10%.

Variables Operationalization

Technological innovations.

Following previous literature (Autio, Sapienza, & Almeida, 2000; Smith, Collins, & Clark, 2005), I developed a two-item scale to measure the degree of innovativeness. The respondents were asked to indicate their degree of agreement with the following statements using a five-point Likert scale ranging from 1 to 5:

(Scale 1–5: Strongly Agree–Strongly Disagree)

“We used all existing knowledge to build the first product, service or technology.”

“We synthesized existing knowledge to produce our first product, service or technology.”

The cronbach alpha 0.8905 supported the internal consistency validity of this two-item scale.

Social capital.

Social capital can be measured by two methodologies: name generator, and position generator. Name generator method allows a thorough measurement of the structural properties of networks, and enables one to track down changes in the personal networks of individuals over time. This method has been widely used and accepted (Burt, 1984, 1992; Burt, 1997; Campbell, Marsden, & Hurlbert, 1986; Lin, 1999; Scott, 1991). The downside of this method is that people tend to remember better the strong ties (Lin, 2001b). Less common than the name generator method, the position generator methodology captures occupational or positional characteristics of network alters, and enables one to collect data on strong and weak ties simultaneously (Lin, 2001b). The downside of this method includes the limitations to conducting a thorough structural analysis of networks such as the estimation of structural holes, and a potential bias of social desirability. Respondents may overstate the number of powerful and resourceful contacts they had. However, the position generator methodology has been used fruitfully (Batjargal, 2003; Belliveau, O'Reilly, & Wade, 1996; Lin et al., 1986).

I chose the position generator method for this study because this method is more appropriate to collect data on network structure, relational and resource dimensions simultaneously (Lin, Fu, & Hsung, 2001). In the pilot study, the respondents found it very time-consuming to answer the questions generated by the name generator method. Very few people could generate more than 7 names, and usually they ignored their weak ties. The position generator method allows the respondents to summarize their social contacts in each occupation, and report the tie strength simultaneously.

A table was presented in which 18 types of occupations are listed in rows, and three types of tie strength (Relatives, Friends, Acquaintances) are placed in columns (Lin et al., 1986;

Lin et al., 2001). The respondents were asked to indicate how many people were in each cell. I developed the following eighteen types of occupations based on the research of numerous previous studies (e.g. Batjargal, 2003; Belliveau et al., 1996; Cooke & Wills, 1999; Dakhil & Clercq, 2004; Erickson, 2004; Lin et al., 1986; Lin et al., 2001; Van der Gaag & Snijders, 2004): Professionals in universities, research institutes and government labs; Professionals in trade associations and industry associations; Managers of large banks, venture capital firms or other financial institutions; Other staff members of large banks, venture capital firms or other financial institutions; Managers of medium and small banks, venture capital firms or other financial institutions; Other staff members of medium and small banks, venture capital firms or other financial institutions; Owners or managers of large firms in your own industry; Other staff members of large firms in your own industry; Owners or managers of medium and small firms in your own industry; Other staff members of medium and small firms in your own industry; Owners or managers of large firms in different industries; Other staff members of large firms in different industries; Owners or managers of medium and small firms in different industries; Other staff members of medium and small firms in different industries; High-rank official in local governments; Middle- and low-rank official in local governments; High-rank official in ministries and agencies; Middle- and low-rank official in ministries and agencies. These social ties are critical for the entrepreneurs to seek advice, obtain funding, establish cooperative relationships, and promote their products or services. Using this methodology, I measured a person's access to occupational positions through social relationships. This method is *theoretically meaningful* because occupation plays an important role in modern societies. A person's occupation indicates their social resources.

People who know others in a wide variety of occupations can access the broader range of various resources. Researchers can measure the network diversity with the position generator by counting up the number of different kinds of occupations in which a person knows someone. In this dissertation, I used the Entropy index (Hoskisson et al., 1993; Jacquemin et al., 1979; Palepu, 1985) to measure the diversity of social capital.

The diversity of social capital measures the degree to which an egocentric network contains alters from diverse occupations. The entropy measure measures the degree of dispersion of business ties in various occupations by multiplying a weight variable $\ln(1/p_i)$. The diversity measure was computed for both the startup stage and the expansion stage.

$$\text{Entropy Measure} = \sum_i [p_i \times \ln(1/p_i)]$$

where P_i is defined as the proportion of occupation i 's business contacts in all business ties and $\ln(1/p_i)$ is the weight for each occupation i .

Entrepreneurial cognitions.

Causal maps are representations of individuals (or groups) beliefs about causal relations. Since being introduced to management studies (Axelrod, 1976a), it has been used for investigating managers and decision makers. Causal maps are partial descriptions of belief structures because we elicit particular objects or construct from individuals on a certain subject. Causal mapping is a type of content analysis that isolates the key statements within a document that deals with causality, existence, or categorization of relevant issues in strategic decision making (Eden et al., 1992; Huff, 1990). To construct

a causal map, the first step is to develop a pool of constructs by conducting and analyzing interviews with managers and a review of relevant literature. The questionnaire items on cognitions were finalized based on the review of relevant literature and a pilot test. In the second step, have each subject select a fixed number of constructs by identifying items from a constant pool of constructs. Finally, construct the causal map of each individual subject by having her/him assess the influence of each of her/ his selected constructs on her/his other selected constructs.

In this study, to improve the validity of cognitive measures and expedite the mapping process, the questionnaire asked the respondents to construct the causal relations between identified concepts directly. From a list of concepts generated from the innovation literature, each respondent selected the concepts they think important for new venture innovations, ranked the chosen concepts and established the causal relationship between these concepts. This is an efficient and effective way to capture each respondent's mental map of new venture innovation. I input each causal map matrix into the UCINET software (Borgatti, Everett, & Freeman, 2002) to compute the centrality and complexity measures of entrepreneurial cognitions. From the previous literature (Biemans, 1991; Cooper, 1984; Deshpande, Farley, & Webster, 1993; Gatignon & Xuereb, 1997; Kohli & Jaworski, 1990; Narver & Slater, 1990; Powell, Koput, Bowie, & Smith-Doerr, 2002; Powell et al., 1996; Sapienza, 1992; Saxenian, 1990; Shan et al., 1994; Slater & Narver, 1999; Todtling & Kaufmann, 2002; Tyler & Gnyawali, 2002; Voss & Voss, 2000; Workman, 1993), I generated the following concepts: Anticipate customers needs, Building market share, Encourage customer retention, Appropriate response to target market growth projections, Product builds on firms technological competencies,

Coordination of design specifications with operations, Parallel development efforts across divisions, Satisfy customers needs, Competitors innovation activities, Competitors cost advantage, Speed of competitor response, Anticipate competitors moves, Consistent investment in R&D, Existing capabilities to develop new products/services, Potential to patent new products/designs, Coordination between manufacturing and R&D, Flow of market information between units, Venture capital involvement, Joint research and development with business partners and/or research institutes.⁸

Complexity of the mental model.

Complexity of the mental model is measured by the density of a causal map. The density of a causal map refers to the ratio of causal links to the total number of constructs in the causal map (Eden et al., 1992). A higher ratio indicates that the entrepreneur's cognitive map is densely connected and supposedly a higher level of cognitive complexity.

$$C_{complexity} = \frac{links}{constructs}$$

Centrality of the mental model.

I used the established network-based measure of centrality (Eden et al., 1992) to calculate the degree centrality of each chosen concept and gives the overall cognitive map

⁸ This method of capturing respondents' mental models is built on the previous literature. For example, Tyler, B. B. & Gnyawali, D. R. 2002. Mapping managers' market orientations regarding new product success. The Journal of Product Innovation Management, 19: 259-276. The concepts identified in this paper are as follows: 1. anticipation of customer needs; 2. building market share; 3. being proactive in dealing with competition; 4. competitors' cost advantage; 5. consistent investment in R&D; 6. Coordination between manufacturing and R&D; 7. coordination of design specifications with operations; 8. current capability to develop new products; 9. encouragement of customer retention; 10. flow of market information between units; 11. interdepartmental coordination; 12. likelihood that competitors will soon introduce new products; 13. parallel development efforts across divisions; 14. possibility that competitors will introduce substitutes; 15. potential to patent new products; 16. potential to strengthen firm's technological capability; 17. product builds on firm's technological competencies; 18. response to target market growth projections; 19. satisfaction of customer needs; 20. speed of competitor response.

centralization. Centrality of each concept in the causal map was measured by adding the total number of concepts to which a specific concept in the map is linked either directly or indirectly. Each successive layer of concepts was assigned a diminishing weight. The centrality of a concept is the weighted average length of all the total paths that link it to other concepts in the map. The centrality of the causal map is the centrality of the most central concept minus the centrality of all other concepts in the map scaled by the total number of possible links between the concepts in the map (Borgatti et al., 2002; Freeman, 1979).

$$C_{Centrality} = \frac{\sum_{i=1}^n [C_{Centrality}(p^*) - C_{Centrality}(p_i)]}{\max \sum_{i=1}^n [C_{Centrality}(p^*) - C_{Centrality}(p_i)]}$$

$$C_{Centrality}(p_i) = \sum_{i=1}^n a(p_i, p_k)$$

where $a(p_i, p_k) = 1$ if and only if p_i and p_k are connected by a line

0 otherwise

$C_{Centrality}(p^*) =$ largest value of $C_D(p_i)$ for any concept in the map

and

$\max \sum_{i=1}^n [C_{Centrality}(p^*) - C_{Centrality}(p_i)] =$ the maximum possible sum of differences in point

centrality for a map of n concepts.

Control variables

Entrepreneur's characteristics.

In the questionnaire, respondents were asked to report age, gender, level of education, level of involvement in social activities, length of working experience, level of ownership,

and startup experience. Numerous previous studies have shown that these factors play significant roles in new venture innovation. Among all these variables, the level of involvement in social activities is noteworthy. Since the respondents were asked to report their business ties, it is essential to control their level of participation in social activities the aggregate level. They are asked to indicate the level of involvement (minimal, regular and heavy) for seven types of organization/club/group (Professional association, Trade association, Alumni association, Athletic club, Political party, Religious group, and Other).

Firm Characteristics.

The questionnaire asked the respondents to report the industry, size, and history of the firm as well as the proportion of R&D expenditure in its annual sales. The following questions are asked in the survey to obtain these control variables:

“When was your company founded?”

“Number of current employees”

“On average, how much is invested annually by your company in R&D as a percentage of sales?”

Analysis and Findings

I used general least squares modeling to analyze the data. The model I used to test hypotheses 2, 3a and 3b is represented by the following equation: $y_i = x_i\beta + \varepsilon_{it}$

where y_i is the degree of innovativeness of firm i ; x_i is a vector of characteristics of firm i , including the independent variables and control variables; and ε_i is an error term.

The model I used to test hypotheses 1a and 1b is represented by the following equation:

$$y_i = x_i\beta + \varepsilon_i$$

where y_i is the cognitive structure properties of respondent i ; x_i is a vector of characteristics of firm i , including the independent variables and control variables; and ε_i is an error term.

Table 1 presents a summary of the constructs, and corresponding proxies. Table 2 presents the descriptive statistics and correlation matrix of all the variables. It is noteworthy that, even without controlling any other effects, the correlation between social capital diversity (startup stage) and cognitive complexity is significant at .01 level. Social capital diversity (startup stage) and social capital diversity (expansion stage) is strongly correlated, which indicates that the business contacts at the startup stage may introduce more business contacts for the entrepreneur. Cognitive complexity and cognitive centrality is strongly correlated, which means an actor with more complex cognitive structure is more likely to develop the ability of differentiating the core factors from the peripheral factors.

Chapter V Table 1: Summary of Constructs, and Corresponding Proxies

Constructs	Proxies
Degree of innovativeness	5-point Likert scale
Social capital diversity	Social relations Entropy index
Cognitive centrality	Cognitive map centrality
Cognitive complexity	Cognitive map density
Firm size	No. of employees
Firm history	Years of operations
R&D investment	Proportion of R&D expenditure in annual sales
Degree of participation in social activities	Level of involvement for organization/club/group
Entrepreneur's age	Age
Entrepreneur's gender	Gender
Entrepreneur's level of education	Highest degree received
Entrepreneur's working experiences	Years of working experience in the industry
Industry factor	Industry dummy (0: non high-tech; 1: high-tech)
Ownership	Percentage of ownership in the firm
Startup experience	Startup experience dummy (0: no startup experience; 1: startup experience)

Chapter V Table 2: Pearson Correlations^a

	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 Degree of innovativeness	2.129	0.992																
2 Cognitive centrality	0.178	0.145	-.114															
3 Cognitive complexity	0.581	0.621	-.212†	.712***														
4 Social capital diversity (startup stage)	1.086	0.559	.095	.148	.351**													
5 Social capital diversity (expansion stage)	1.005	0.630	.018	.042	-.042	.424***												
6 Firm size	20.229	39.002	-.097	-.056	-.046	-.110	.102											
7 Firm history	11.464	6.103	-.039	.118	.142	-.059	-.068	.019										
8 R&D investment	3.580	2.452	.037	.234†	.178	.074	.204	-.030	-.033									
9 Participation in social activities	3.529	2.198	.068	-.095	.105	.367**	.239†	.057	-.170	-.189								
10 Age	4.043	1.042	.191	-.153	-.116	-.200	-.053	.053	.443***	-.168	-.124							
11 Gender	1.129	0.337	-.007	.226†	.122	.085	-.263*	-.135	.031	-.057	-.171	-.264*						
12 Education	3.429	2.352	-.089	.280*	.315**	-.045	.067	.210†	-.145	.289*	-.046	-.247*	.112					
13 Working experience	19.514	9.930	.061	-.058	-.208†	-.115	.053	.185	.178	-.089	-.201†	.498***	-.163	-.143				
14 Industry dummy	0.662	0.477	-.303*	.254*	.231†	-.197	.081	.113	.195	.364**	-.082	-.118	-.179	.314**	-.091			
15 Ownership	9.043	3.141	.124	.116	.035	.040	-.051	-.295*	.151	-.158	-.270*	-.054	.132	-.056	.012	-.040		
16 Startup experience dummy	0.500	0.504	.044	-.037	-.072	-.064	-.033	-.092	-.024	.111	-.046	.180	-.043	-.281*	.119	-.259*	-.005	

^a 57 ≤ N ≤ 70.

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Chapter V Table 3: Effect of Social Capital Diversity on Cognitive Complexity ^a

	Model 1	Model 2	Model 3	Model 4
(Constant)	-.525 (.844)	-.568 (.746)	-.424 (.847)	-.157 (.724)
Firm size	-.001 (.002)	-.002 (.002)	-.001 (.002)	-.001 (.002)
Firm history	.021 (.017)	.012 (.015)	.021 (.017)	.009 (.014)
R&D investment	.029 (.041)	-.013 (.038)	.036 (.042)	.006 (.037)
Participation in social activities	.062 (.044)	-.013 (.044)	.067 (.045)	-.011 (.042)
Age	-.012 (.111)	.036 (.099)	-.013 (.111)	.045 (.093)
Gender	.267 (.310)	.057 (.280)	.230 (.309)	-.164 (.279)
Education	.060 (.047)	.072† (.042)	.058 (.047)	.066 (.040)
Working experience	-.008 (.010)	-.013 (.009)	-.009 (.010)	-.015 (.009)
Industry dummy	.168 (.239)	.374† (.219)	.137 (.229)	.315 (.208)
Ownership	.012 (.031)	-.014 (.029)	.016 (.031)	-.008 (.027)
Startup experience dummy	.079 (.206)	.157 (.184)	.047 (.201)	.053 (.178)
Social capital diversity (startup stage)		.638*** (.179)		.834*** (.187)
Social capital diversity (expansion stage)			-.084 (.152)	-.370* (.151)
R ²	.238	.419	.243	.495
F	1.195	2.46*	1.125	3.011**

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses.

N=55

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Chapter V Table 4: Effect of Social Capital Diversity on Cognitive Centrality^a

	Model 1	Model 2	Model 3	Model 4
(Constant)	-.040 (.169)	-.046 (.161)	-.011 (.173)	-.022 (.167)
Firm size	.000 (.000)	.000 (.000)	-7.291E-05 (.000)	.000 (.000)
Firm history	.001 (.003)	-.001 (.003)	.001 (.003)	-.001 (.003)
R&D investment	.006 (.008)	.001 (.008)	.008 (.009)	.002 (.008)
Participation in social activities	.003 (.009)	-.007 (.010)	.003 (.009)	-.007 (.010)
Age	-.029 (.022)	-.022 (.021)	-.029 (.023)	-.022 (.022)
Gender	.107† (.062)	.078 (.061)	.094 (.063)	.065 (.064)
Education	.002 (.009)	.003 (.009)	.000 (.010)	.003 (.009)
Working experience	.001 (.002)	.000 (.002)	.000 (.002)	2.672E-05 (.002)
Industry dummy	.083† (.048)	.111* (.047)	.064 (.047)	.107* (.048)
Ownership	.009 (.006)	.005 (.006)	.010 (.006)	.005 (.006)
Startup experience dummy	.032 (.041)	.042 (.040)	.017 (.041)	.036 (.041)
Social capital diversity (startup stage)		.086* (.039)		.098* (.043)
Social capital diversity (expansion stage)			-.003 (.031)	-.022 (.035)
R ²	.300	.376	.283	.382
F	1.638	2.055*	1.384	1.900†

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses.

N=55

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Table 3 and 4 present the results from the least squares regression analysis. Models in Table 3 include firm size, history, R&D investment, entrepreneur's age, gender, education level, working experience, level of participation in social activities, industry dummy, ownership, and startup experience as control variables. The social capital diversity (startup stage) has a positive and significant effect on the entrepreneur's cognitive complexity. Firm industry and entrepreneur's education level are marginally significant. This regression analysis supports Hypothesis 1a: The diversity of an entrepreneur's social capital is associated positively with their cognitive complexity.

Models in Table 4 include firm size, history, R&D investment, entrepreneur's age, gender, education level, working experience, level of participation in social activities, industry dummy, ownership, and startup experience as control variables. The social capital diversity (startup stage) has a positive and significant effect on the entrepreneur's cognitive centrality. Firm industry is also significant. This regression analysis supports Hypothesis 1b: The diversity of an entrepreneur's social capital is associated positively with their cognitive centrality.

Chapter V Table 5: Effects of Social Capital Diversity, Cognitive Centrality, and Cognitive Complexity on Degree of Innovativeness^a

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	.121 (1.115)	.162 (1.130)	-.184 1.119	-.128 1.073	-.120 1.076	-.088 1.099	-.088 1.119	-.181 1.129
Firm size	.001 (.003)	.001 (.003)	.000 .003	.001 .003	.001 .003	.001 .003	.001 .003	.001 .003
Firm history	-.030 (.023)	-.029 (.024)	-.022 .024	-.019 .023	-.022 .023	-.028 .023	-.028 .024	-.023 .024
R&D investment	.138* (.057)	.145* (.061)	.144* .060	.151** .055	.157** .055	.152** .057	.152* .060	.147* .061
Participation in social activities	.079 (.059)	.092 (.069)	.091 .067	.109† .058	.100† .059	.087 .058	.087 .068	.090 .068
Age	.347* (.154)	.338* (.158)	.362* .154	.330* .147	.315* .149	.315* .152	.316* .155	.348* .161
Gender	.240 (.407)	.264 (.416)	.312 .407	.328 .391	.407 .403	.438 .415	.438 .421	.361 .433
Education	-.004 (.061)	-.006 (.061)	.033 .064	.011 .059	.008 .059	.010 .060	.010 .061	.028 .065
Experience	-.003 (.014)	-.003 (.014)	-.007 .014	-.008 .013	-.006 .014	-.002 .014	-.002 .014	-.006 .015
Industry dummy	-.767* (.317)	-.808* (.338)	-.688* .336	-.759* .289	-.734* .292	-.671* .315	-.671† .341	-.671† .343
Ownership	.066 (.044)	.069 (.045)	.069 .044	.085* .040	.091* .041	.082† .044	.082† .045	.074 .046
Startup experience dummy	-.313 (.276)	-.330 (.282)	-.282 .276	-.292 .253	-.302 .254	-.277 .271	-.277 .278	-.276 .279
Social capital diversity (startup stage)		-.100 (.265)	.098 .280				.000 .266	.081 .286
Cognitive complexity			-.434† .234	-.394† .200	-.197 .307			-.319 .403
Cognitive centrality					-1.227 1.453	-1.819† 1.032	-1.820† 1.069	-.646 1.830
R ²	.257	.259	.307	.322	.332	.300	.300	.309
F	1.602	1.455	1.673†	2.102*	1.984*	1.788†	1.617	1.535

^a The table gives parameter estimates; the standard error is below each parameter estimate in parentheses.

63 ≤ N ≤ 66

† $p < .1$ (two-tailed)

* $p < .05$ (two-tailed)

** $p < .01$ (two-tailed)

*** $p < .001$ (two-tailed)

Models in Table 5 include firm size, history, R&D investment, entrepreneur's age, gender, education level, working experience, level of participation in social activities, industry dummy, ownership, and startup experience as control variables. In Model 3 and 4, cognitive complexity has a negative and marginally significant effect on the firm's degree of innovativeness. R&D investment, age, industry dummy, and ownership are also significant. In Model 6, cognitive centrality has a negative and marginally significant effect on the firm's degree of innovativeness. R&D investment, age, industry dummy, and ownership are also significant. This analysis found a weak negative relationship between cognitive complexity and degree of innovativeness, so is between cognitive centrality and degree of innovativeness.

Discussion

This chapter presents the second empirical test of the theoretical model proposed in Chapter III. I derived five hypotheses linking entrepreneur's social capital, cognitions and new venture innovation. The analysis results of a sample of surveyed small and medium-sized technology firms are, for the most part, consistent with the hypotheses. Actors' cognitions have significant effects on the degree of new venture innovativeness. In addition, an entrepreneur's social capital influences the entrepreneurial cognition of new venture innovation. Hypotheses 1a, 1b, and 3b were supported; meanwhile, a negative, instead of positive, relationship between cognitive complexity and degree of innovativeness was found significant. The possible explanation is that some respondents' firms are operating in the traditional manufacturing industries, particularly the sampled firms in Pennsylvania. Although technologies are involved in the manufacturing process, these new ventures had to explore new knowledge domains to produce their first product,

service or technology in these mature industries. Conversely, in the emerging high-technology industries, new ventures can survive by leveraging existing knowledge and technologies. Both the correlation matrix and Table 5 provided evidence that industry dummy is negatively correlated with degree of innovativeness. The implication is that SMEs in high-tech industries tend to rely on existing knowledge bases to develop product, services, or technologies; whereas SMEs in non high-technology industries tend to explore new knowledge domains to develop their businesses. Moreover, cognitive complexity is positively correlated with industry dummy. In the high-technology industries, entrepreneurs tend to have a more complex mental model. The combined effect of these two correlations significantly influences the analysis results of this study. Furthermore, because the respondent is the sole data source for both independent variables and dependent variable, common method variance (Avolio, Yammarino, & Bass, 1991; Podsakoff & Organ, 1986) could be a problem in this study. Systematic errors arising out of it can introduce spurious correlation between the variables. Future research could address this issue by focusing on a single industry or use objective measures of firm innovativeness.

Chapter VI CONCLUSION

This dissertation was intended to explore the social and cognitive origins of firm innovation. In this research, I proposed a theoretical model linking social capital, cognitive structure, and firm innovation. To test this model's validity, I used a combination of methods to analyze both small and medium-sized private firms and public corporations. This chapter summarizes the key findings and contributions of these studies, and discusses the limitations of this research and directions for future research.

Summary of Major Findings

	1st Empirical Study (Chapter IV)	2nd Empirical Study (Chapter V)
Social capital – cognitive structure	Diversity of a firm's social capital: cognitive centrality (+ supported)	Diversity of an entrepreneur's social capital: cognitive complexity (+ supported) Diversity of an entrepreneur's social capital: cognitive centrality (+ supported)
Social capital – firm innovation	Diversity of a firm's social capital: exploitation (+) Diversity of a firm's social capital: exploration (-)	
Cognitive structure – firm innovation		The entrepreneur's cognitive complexity: degree of innovativeness (- marginal) The entrepreneur's cognitive centrality: degree of innovativeness (- marginal)

+ indicates a positive relationship, while – indicates a negative relationship.

Answers to Research Questions

Through these interrelated studies, I addressed the set of questions put forward in Chapter I.

How do social capital and the embedded actors' cognitive structure influence each other?

One objective of this research was to incorporate the actors' cognitive structure in the social capital studies. Actors actively identify available relationships and the resources that they perceive will be accessible through social relationships. In the second empirical study, entrepreneurs' social capital at the startup stage influences their cognitive structure of firm innovation. In a diverse social network, actors' knowledge structure tends to be more complex, and more centralized. This finding highlights the importance of entrepreneurs' social networking activities during the startup stage. When uncertainty is high, entrepreneurs should turn to different contacts to seek advice, establish cooperative relationships, and obtain funding. These business contacts not only provide external resources to the entrepreneurs, but also influence positively their internal cognitive structure. This reinforcing effect of social capital helps the formation of innovation networks. This finding also implies that the networking activities between different industries and regions could benefit the participants' knowledge structures. Business networking for small and medium-sized enterprises could be a means to promote regional competitiveness.

How does social capital influence firm innovation?

I argued that social capital has an impact on firm innovation. The first empirical study supports the prediction that social capital diversity affect an important element of an organization's life – technological innovation. For the technology firms, diversity of social

capital was found to be a significant variable in firm innovation. It is associated positively with rate of innovation, negatively with exploration, and positively with exploitation.

Although exploitative activities may drive out exploratory activities, established firms in the semiconductor industry could pursue exploitation and exploration simultaneously in organizational learning. This finding implies that specific types of alliance partners make more contribution to exploratory technological innovations.

How does cognitive structure influence firm innovation?

In the second empirical study, both cognitive complexity and cognitive centrality are negatively correlated with degree of innovativeness of SMEs. The negative correlation between cognitive centrality and degree of innovativeness is consistent with my hypotheses. I discussed the possible explanations for the negative correlation between cognitive complexity and degree of innovativeness (chapter V). Some established semiconductor firms ally actively with their potential customers to exploit their existing skills and capabilities, whereas new entrants focus their networking activities on certain type of partners to explore new technological domains. Future research could address this issue and analyze the specific partners of inter-firm alliances. Entrepreneurs of high-technology firms tend to have a more complex cognitive structure. However, these high-technology new ventures rely more on existing knowledge to develop new products, services, and technologies. The industry factor plays a significant role in this study. This industry-specific influence reveals the necessity of focusing the future studies on one single industry to rule out the industry effect.

Contributions

This dissertation merged several research streams – social networks, managerial cognitions, and firm innovation – and used data collected through multiple methods – archives and surveys – to investigate the social and cognitive origins of firm innovation. First I proposed a theoretical model linking social capital, cognitions, and firm innovation. Next I tested this model in two empirical contexts - U.S. semiconductor firms, and a sample of small and medium-sized firms in Pennsylvania and Virginia. My research makes important theoretical and methodological contributions. It extends several sets of literature – organization theory and firm innovation, as does organizational research methodologies.

Organization theory

As the “final arbiter of competitive success” (Burt, 2000), social capital has significant effects on the embedded actors’ cognitive structures, and firm’s search activities in technological innovations. First, this dissertation attempted to establish the link between social networks and managerial cognitions. In the strategic management research, few known studies have explicitly linked managerial cognitions research with social networks studies, and no previous research has tested the effects of social networks and managerial cognitions on technological innovations at the same time. The research findings reveals the decision process in the selection of relationships, which has been taken for granted in social network studies. Existing social network research treats individuals as identical, and has not considered the role of individual differences that influence the realized benefits of social networks (Gargiulo et al., 2000; Kilduff et al., 2000a; Reagans et al., 2001). An adequate analysis of network includes the capacity of the actors to transform or reproduce long-term structures (Harrison et al., 2002). By incorporating the actors’ cognitions into

their social capital to study the business phenomenon of firm innovation, this dissertation attempts to develop a theory of action which connects individual interests with social structure (Coleman, 1986; Poole & Vandeven, 1989).

Firm innovation

Depending on the embedded actors' cognitive idiosyncrasies, social capital has contingent effects on firm innovation. This research contributes to a richer understanding of the sources and process of firm innovations. By examining the public corporations and private new ventures, my study provided a comprehensive look at the role of external social capital and internal cognitive structure in firm innovation. The analysis results suggest that business networking with diverse others appear to drive local search and exploitation based on familiar knowledge. Firms face challenges in maintaining exploration into new domains, when their business networks are homogeneous, and when their top management team focuses on extremely limited strategic factors. The research findings have broad implications for practitioners in the technology firms and the support network consisting of venture capitalists, lawyers, accountants, and policy makers. The proposed theoretical model that describes the mechanisms by which social capital and cognitions influence innovation process, has important implications for managerial practice, especially in market domains where firm performance is strongly driven by innovation success. It helps managers to focus on the specific aspects of their cognitive structures and social capital in the process of innovation.

Research methodologies

Top management team's or entrepreneurs' cognitive idiosyncrasies were operationalized and tested. Empirical measures of latent constructs, such as cognitive complexity and

centrality, were developed. The proposed theoretical model was empirically tested in two studies using data collected through multiple methods.

The first empirical study is based on a longitudinal study of the U.S. semiconductor firms. First, this work goes beyond prior research by incorporating measures of cognitive structures that are comparable across firms. Second, exploitative and exploratory search in technological innovations were measured along two dimensions, using a comprehensive method (Benner et al., 2002; Katila et al., 2002). Third, this empirical design provides a robust test of hypotheses relating social capital, cognitive structures, and technological innovation. The panel study relies on longitudinal data and within-firm variation to assess the effects of social capital and cognitive structures on technological innovation. This design helps control for confounds that arise from comparisons between firms, which cannot easily distinguish unobserved factors that influence business networking and cognitive structures from factors that influence patenting behavior. Furthermore, constraining this study to a single competitive context helps mitigate concerns that arise from differences in patenting practices between industries (Ahuja, 2000a). Last but not the least, I used a complex, multistage computer-assisted content analysis of archival data to derive the measures of company-level cognitive structures of top management team. Using statistical methods to find high-value information clusters, or 'hot spots' (Ramaprasad, 1996), permits large-scale analysis and inter-firm comparison. Although this data mining method needs further improvement and refinement, it is an enhancement of traditional content analysis, and enables scholars to conduct more large-scale empirical studies in the area of managerial cognition.

In conclusion, by distinguishing between cognitive structures as well as social network characteristics and by examining the interrelationships between cognitions, social networks and innovation, this dissertation research extends the theoretical and empirical research on organization theory, and firm innovation.

Limitations and Directions for Future Research

By exploring the effects of social capital and actors' cognitions on firm innovation, the goal of this dissertation research was to examine the social and cognitive sources of innovative activities in a firm. The results are, for the most part, consistent with the hypotheses developed based on the theoretical model presented in Chapter III. Social capital and actors' cognitions have significant effects on the degree of firm innovativeness.

Despite the contributions this dissertation research is expected to make, several unanswered questions remain, providing important directions for future research. First, there might be an interaction between actors' cognitions and social capital in the context of firm innovation. Future research could examine this interactive effect on firm's technological innovation. Second, a longitudinal study could examine the dynamic innovation process which was indicated as the self-reinforcing feedback loop in Figure 2. If technology startups could be traced over time, future research can empirically test Proposition 2, 6 and 7. Third, future research would be well-served to conduct comparative research across industries as well as across countries. Fourth, high-technology regions play a leading role in technological innovations. Future research could target the technology startups in these regions such as the Silicon Valley of California and Research Triangle Park of North Carolina. Regional competitiveness continues to come from innovative

networks. In an incubator park, local policy and service firms play key roles in establishing the scaffolding for the embedded entrepreneurs and their new ventures. Future research could study the effects of these institutions on the entrepreneurs' cognitions and social networks. Methodologically, future research can further explore the variation on the integration of qualitative and quantitative research designs to overcome the statistical limitations of anecdotal evidence. Finally, assessing managers' cognitive structure's influence on innovation activities is a first step in exploring its impact on organizational outcomes. Further research could study the effects of senior managers' cognitive structure on other organizational outcomes such as profitability, stock price, etc.

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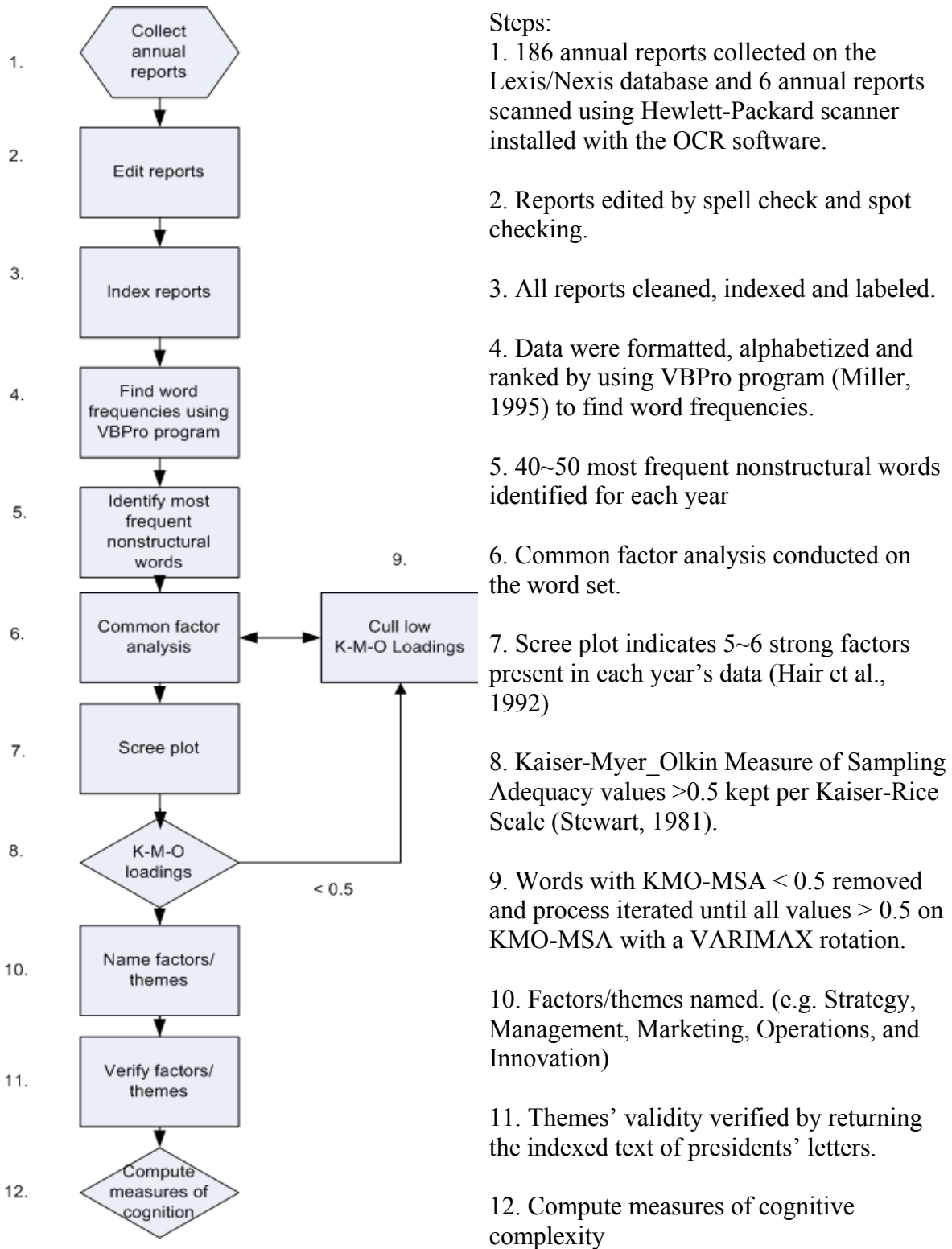
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APPENDICES

Appendix A: Patent Classification Codes

Patent class	Title
136	Batteries: Thermoelectric and Photoelectric
174	Electricity: Conductors and Insulators
200	Electricity: Circuit Makers and Breakers
219	Electric Heating
250	Radiant Energy
257	Active Solid-State Devices (e.g., Transistors, Solid-State Diodes)
307	Electrical Transmission or Interconnection Systems
310	Electrical Generator or Motor Structure
313	Electric Lamp and Discharge Devices
315	Electric Lamp and Discharge Devices: Systems
318	Electricity: Motive Power Systems
320	Electricity: Battery or Capacitor Charging or Discharging
322	Electricity: Single Generator Systems
323	Electricity: Power Supply or Regulation Systems
324	Electricity: Measuring and Testing
326	Electronic Digital Logic Circuitry
327	Miscellaneous Active Electrical Nonlinear Devices, Circuits, and
329	Demodulators
330	Amplifiers
331	Oscillators
332	Modulators
335	Electricity: Magnetically Operated Switches, Magnets, and
336	Inductor Devices
337	Electricity: Electrothermally or Thermally Actuated Switches
338	Electrical Resistors
361	Electricity: Electrical Systems and Devices
363	Electric Power Conversion Systems
377	Electrical Pulse Counters, Pulse Dividers, or Shift Registers: Circuits and
381	Electrical Audio Signal Processing Systems and Devices
392	Electric Resistance Heating Devices
429	Chemistry: Electrical Current Producing Apparatus, Product, and Process
438	Semiconductor Device Manufacturing: Process
439	Electrical Connectors
445	Electric Lamp or Space Discharge Component or Device Manufacturing
505	Superconductor Technology: Apparatus, Material, Process

Appendix B: A Multi-stage Computer-assisted Content Analysis of Presidents' Letters to Shareholders



Appendix C: Survey Questionnaire

A SURVEY ON FIRM INNOVATION

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You have been invited to participate in a survey on firm innovation. Innovations are critical to business success. This research examines the success factors of firm innovations. Your completion of the following survey will help us with this research effort. If you have ever STARTED a company, please complete the survey, regardless of the current status of the company. Time of completion is expected to be only 20 to 25 minutes.

There are no foreseeable risks associated with this project, and your participation in this study is completely voluntary. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. You may also withdraw from participation at any time should the questions make you feel uncomfortable. Should you choose, you will also receive an analysis report once we complete this research (by June 30th 2006). This analysis report will help you make better business decisions. In addition, one prize (a \$35 gift card) will be randomly drawn out of every five VALID responses. The winner will be notified immediately after each sweepstake from now until March 31st 2006.

If you have questions at any time about the survey or the procedures, you may contact the principal investigator, Yang XU, at 724-334-6715 or by email at yux4@psu.edu. Yang is a business faculty member of Penn State University (New Kensington campus). Thank you very much for your time and support.

Would you like to receive an analysis report? Yes No

Would you like to enter the gift card sweepstake? Yes No

How did you learn about this survey?

Direct contact from researcher Friend/colleague Incubator

Professional/social organization Other _____

Next please enter your contact information and company name below:

Your name _____

Email: _____

Company name: _____

Company's five-digit zip code: _____

A. Company Snapshot

1. What industry best describes your business?

- Aerospace and defense
- Environmental science
- Semiconductor/ Microelectronics
- Biotechnology
- Internet/Online services
- Software/applications
- Chemicals
- Materials Science/ Nanotechnology
- Telecommunications/IT
- Computer/peripherals
- Pharmaceuticals
- Other high technology
- Education/training
- Professional/consulting services
- other non high technology

2. When was your company founded? (mm/yyyy) _____

3. Number of current employees: _____

4. What percentage of the company that you founded do you currently own?

- Out of business
- N/A
- <10%
- 10% - 19.99%
- 20% - 29.99%
- 30% - 39.99%
- 40% - 49.99%
- 50% - 59.99%
- 60% - 69.99%
- 70% - 79.99%
- 80% - 89.99%
- 90% - 100%

5. Have you participated in start-ups other than your current business? (If no, please go to Question 6.)

- Yes
- No
- Not applicable

If yes, how many were successful? _____ And please list the type of business and your level of involvement in the most recent two businesses:

a. Type of the most recent business:

- Aerospace and defense
- Environmental science
- Semiconductor/ Microelectronics
- Biotechnology
- Internet/Online services
- Software/applications
- Chemicals
- Materials Science/ Nanotechnology
- Telecommunications/IT
- Computer/peripherals
- Pharmaceuticals
- Other high technology
- Education/training
- Professional/consulting services
- other non high technology

Involvement: Founder Investor Director Advisor Other

b. Type of the second recent business:

- Aerospace and defense
- Environmental science
- Semiconductor/ Microelectronics
- Biotechnology
- Internet/Online services
- Software/applications
- Chemicals
- Materials Science/ Nanotechnology
- Telecommunications/IT

- Computer/peripherals Pharmaceuticals Other high technology
 Education/training Professional/consulting services other non high technology

Involvement: Founder Investor Director Advisor Other

6. Are you the single founder of this new venture? Yes No

If no, how many people are in your founding team, including you? _____

7. Are you a member of any organization/club/group? If yes, please indicate your level of involvement for each organization/club/group:

	Minimal	Regular	Heavy
Professional association 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Professional association 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Trade association 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Trade association 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Alumni association 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Alumni association 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Athletic club 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Athletic club 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Political party 1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Political party 2	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Religious group	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

B. Firm Innovation: (Based on the actual situation in this firm, please indicate your agreement with each of the following statements.)

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree	Cannot answer
1. We used all existing knowledge to build the first product, service or technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. We synthesized existing knowledge to produce our first product, service or technology.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. On average, how much is invested annually by your company in R&D as a percentage of sales?						

- | | | | |
|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| <input type="checkbox"/> <3% | <input type="checkbox"/> 3% - 4.99% | <input type="checkbox"/> 5% - 9.99% | <input type="checkbox"/> 10% - 19.99% |
| <input type="checkbox"/> 20% - 29.99% | <input type="checkbox"/> 30% - 39.99% | <input type="checkbox"/> 40% - 49.99% | <input type="checkbox"/> 50% - 59.99% |
| <input type="checkbox"/> Over 60% | | | |

C. Key factors in New Product Development

First step: Please use the small box to check all the factors that you view as important for successful new product development. (Check all that apply.)

Second step: In the blank space, please rank order the chosen factors according to their relative importance for new product development. (1: most important 2: next important; 3: third important; 4 ...)

Third step: Among the chosen factors, please take one factor at a time, and think whether this factor directly causes the other factors you chose. Use arrows to indicate this causal relationship. For example, studying hard → getting a good grade if you think studying hard will result in a good grade. And getting a good grade → studying hard if you think this causal relationship is also valid. (Please do your best on this important question to ensure the quality of your response.)

- | | |
|---|---|
| <input type="checkbox"/> ___ Anticipate customers needs | <input type="checkbox"/> ___ Competitors cost advantage |
| <input type="checkbox"/> ___ Building market share | <input type="checkbox"/> ___ Speed of competitor response |
| <input type="checkbox"/> ___ Encourage customer retention | <input type="checkbox"/> ___ Anticipate competitors moves |
| <input type="checkbox"/> ___ Appropriate response to target market growth projections | <input type="checkbox"/> ___ Consistent investment in R&D |
| <input type="checkbox"/> ___ Product builds on firms technological competencies | <input type="checkbox"/> ___ Existing capabilities to develop new products/services |
| <input type="checkbox"/> ___ Coordination of design specifications with operations | <input type="checkbox"/> ___ Potential to patent new products/designs |
| <input type="checkbox"/> ___ Parallel development efforts across divisions | <input type="checkbox"/> ___ Coordination between manufacturing and R&D |
| <input type="checkbox"/> ___ Satisfy customers needs | <input type="checkbox"/> ___ Flow of market information between units |
| <input type="checkbox"/> ___ Competitors innovation activities | <input type="checkbox"/> ___ Venture capital involvement |
| | <input type="checkbox"/> ___ Joint research and development with business partners and/or research institutes |

D. Entrepreneurs Social Networks Prior to Startup

Please think back to the period just prior to the launch of your business, when you were developing your business plan, planning for your product/service, and seeking funding and potential clients.

You may have sought different people to discuss your business ideas, obtain feedback and other information, and receive support. Please indicate in each cell how many people in each position helped you with the business startup at that time.

	Relatives	Friends	Acquaintances
1. Professionals in universities, research institutes and government labs	___	___	___
2. Professionals in trade associations and industry associations	___	___	___
3a. Managers of large banks, venture capital firms or other financial institutions	___	___	___
3b. Other staff members of large banks, venture capital firms or other financial institutions	___	___	___
4a. Managers of medium and small banks, venture capital firms or other financial institutions	___	___	___
4b. Other staff members of medium and small banks, venture capital firms or other financial institutions	___	___	___
5a. Owners or managers of large firms in your own industry	___	___	___
5b. Other staff members of large firms in your own industry	___	___	___
6a. Owners or managers of medium and small firms in your own industry	___	___	___
6b. Other staff members of medium and small firms in your own industry	___	___	___
7a. Owners or managers of large firms in different industries	___	___	___
7b. Other staff members of large firms in different industries	___	___	___
8a. Owners or managers of medium and small firms in different industries	___	___	___
8b. Other staff members of medium and small firms in different industries	___	___	___
9a. High-rank official in local governments	___	___	___
9b. Middle- and low-rank official in local governments	___	___	___
10a. High-rank official in ministries and agencies	___	___	___
10b. Middle- and low-rank official in ministries and agencies	___	___	___

E. Entrepreneurs Social Networks during Expansion Period:

After the successful launch of your company, you may have sought to expand your company; for example, developing business and new products, increasing the size of company and number of clients. Please indicate how many people in each position helped you during this expansion period.

	Relatives	Friends	Acquaintances
1. Professionals in universities, research institutes and government labs	___	___	___
2. Professionals in trade associations and industry associations	___	___	___

	Relatives	Friends	Acquaintances
3a. Managers of large banks, venture capital firms or other financial institutions	_____	_____	_____
3b. Other staff members of large banks, venture capital firms or other financial institutions	_____	_____	_____
4a. Managers of medium and small banks, venture capital firms or other financial institutions	_____	_____	_____
4b. Other staff members of medium and small banks, venture capital firms or other financial institutions	_____	_____	_____
5a. Owners or managers of large firms in your own industry	_____	_____	_____
5b. Other staff members of large firms in your own industry	_____	_____	_____
6a. Owners or managers of medium and small firms in your own industry	_____	_____	_____
6b. Other staff members of medium and small firms in your own industry	_____	_____	_____
7a. Owners or managers of large firms in different industries	_____	_____	_____
7b. Other staff members of large firms in different industries	_____	_____	_____
8a. Owners or managers of medium and small firms in different industries	_____	_____	_____
8b. Other staff members of medium and small firms in different industries	_____	_____	_____
9a. High-rank official in local governments	_____	_____	_____
9b. Middle- and low-rank official in local governments	_____	_____	_____
10a. High-rank official in ministries and agencies	_____	_____	_____
10b. Middle- and low-rank official in ministries and agencies	_____	_____	_____

F. Demographic Background:

1. Your age: 18-24 yrs. 25-34 yrs. 35-44 yrs. 45-54 yrs. 55-64 yrs.
 65+ yrs.

2. Gender: Male Female

3. What is the highest degree you received?

High school Bachelors MA MS MBA MD
 DSc Ph.D. Other _____

4. What was the last professional position you held before this start-up?

CEO CFO CTO President Business/strategic development
 Customer relations Product development Product project management
 Sales/marketing Other _____

5. How many years have you been working in the current industry? _____

Congratulations - you have successfully completed your responses to this research! If you would like to send comments regarding the survey to the principal investigator or to share your experiences in entrepreneurship in greater detail, please write them in the box provided below or email me at yux4@psu.edu