Exploratory Innovation, The Influence of Core Technical Knowledge Structure and the Breadth of Managerial Attention

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Abstract

Exploratory Innovation, The Influence of
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The purpose of this dissertation is two fold; first, to examine the influence on managerial attention of the structural characteristics in a firm's core technical knowledge portfolio. Second, to examine the influence on exploratory innovation of those structural characteristics as well as the influence of managerial attention. This dissertation draws from resource based theory as well as cognition and recombinant innovation literatures.

First, this dissertation addresses a gap in the attention based theory of the firm (Ocasio, 1997) by examining how Concentration and Ease of Recombination, as structural measures of a firm's core technology portfolio, affect absorptive capacity and therefore the Breadth Managerial Attention. The results of the analysis suggest that both Concentration and the Ease of Recombination are related to the Breadth of Managerial Attention.

Second, this dissertation focuses on exploratory innovation and examines the relationship between a firm's core resource structure and, the theoretically critical but unexamined role of, managerial attention. The Breadth of Managerial Attention is suggested to influence the identification of external knowledge available for the firm to recombine with its core technical knowledge. The results of the analysis

suggest that the Breadth of Managerial Attention plays an important role as the firm creates exploratory innovations.

1. INTRODUCTION

Innovation is a central concept to theories of economic growth (Schumpeter, 1934). In both scholarly and practitioner communities, innovation is considered important to firm performance (e.g. Teece, Pisano, & Shuen, 1997; Walker, 2005) and even firm survival (e.g. Anderson & Tushman, 1990; Tushman & Anderson, 1986). Improved understanding of the factors that influence firm level innovation can contribute to scholarly knowledge (Tushman & Smith, 2002) as well as practice.

Innovation has been defined as the generation of new ideas or new behaviors in organizations (Damanpour & Wischnevsky, 2006). 'New ideas' are often represented in scholarly research by new products (Deeds, DeCarolis, & Coombs, 2000) or new patents representing new knowledge and new technologies (Fleming & Sorenson, 2001). This form of innovation, generally referred to as technical innovation (Bantel & Jackson, 1989; Daft, 1978; Damanpour & Wischnevsky, 2006) is especially important in high technology firms (Schoonhoven, Eisenhardt, & Lyman, 1990) and is the focus of this study.

In general, technical innovation is a well-studied topic (e.g. Anderson, Dreu, & Nijstad, 2004; Damanpour, 1991; Gopalakrishnan & Damanpour, 1997; Tushman & Smith, 2002; Wolfe, 1994). Within the body of innovation research, two major factors are the influence of managerial cognition (e.g. Barringer & Bluedorn, 1999; Damanpour & Schneider, 2006; Eggers & Kaplan, 2008; Kaplan, 2008; Kaplan, Murray, & Henderson, 2003; Yadav, Prabhu, & Chandy, 2007) and the role of the firm's existing knowledge (e.g. Cohen & Levinthal, 1990; Fleming, 2001; Fleming & Sorenson, 2001; Wu & Shanley, 2008; Zahra & George, 2002). The importance of these two factors originates in the epistemological perspective that innovation is a function of the recombination of existing knowledge along with the introduction of new knowledge , inherently a cognitive process (Greve, 1998; Hargadon & Sutton, 1997; Henderson & Clark, 1990; Lant, Milliken, & Batra, 1992; Rosenkopf & Nerkar, 2001; Schumpeter, 1939).

For science intensive high technology firms, current technical knowledge is a critical core resource important to technical innovation performance (e.g. DeCarolis & Deeds, 1999; Wu & Shanley, 2008). In line with Siggelkow (2002), I define core technical knowledge as a firm's explicit technical knowledge that has the potential for or currently creates a high interdependency with other organizational components, or a large influence on future organizational components. A firm's core technical knowledge can be viewed from a portfolio perspective as made up of component knowledge elements that exist in a structural relationship. These knowledge elements are often operationalized using patent data (e.g. Hall, Jaffe, & Trajtenberg, 2001) while their structural relationships have been estimated with different measures of portfolio concentration and ease of recombination that have been linked to technical innovation (e.g. Fleming & Sorenson, 2001; Hall et al., 2001; Wu & Shanley, 2008).

In general, scholarly attention has been more focused on the role of a firm's existing knowledge on technical innovation. However, recent scholarship has called for a greater examination of the role of managerial cognition on a firm's innovative performance (Tushman & Smith, 2002). I addresses this call by examining the breadth of managerial attention (Abrahamson & Hambrick, 1997; Ocasio, 1997) as a mediating construct between the firm's core technical knowledge structure (Barney, 1991; Barney, Wright, & Ketchen Jr., 2001; Fleming & Sorenson, 2001; Grant, 1996) and its' exploratory innovative outcomes.

The acquisition and assimilation of new knowledge (Zahra & George, 2002) is constrained by the localness of search, a cognitively influenced process (Cohen & Levinthal, 1990; Cyert & March, 1963; March & Simon, 1958a; Winter, 2000; Winter, Cattani, & Dorsch, 2007). Local search refers to the exploration of knowledge that is related to a firm's current knowledge. Routines, the value of experience and its effect on performance as well as satisfying behavior and bounded rationality are often noted as the reasons for the dominance of local search (Cyert & March, 1963). Local search, commonly referred to as exploitation, is the predominant search pattern in innovation research (Cyert & March, 1963; March & Simon, 1958a; Nelson & Winter, 1982; Stuart & Podolny, 1996). However, local search is potentially detrimental to long term innovative outcomes and the creation of new knowledge. Concentrating on familiar technologies can preclude the identification of useful technologies that may be technologically distant or may exhaust the set of useful combinatorial possibilities (Fleming & Sorenson, 2001). The challenges posed by local search to innovation have motivated research on exploratory search i.e. search that crosses organizational or technological domains (Rosenkopf & Nerkar, 2001).

This research contributes to this literature by studying the influence of managerial attention on exploratory innovation outcomes.

The dominant process model for managerial cognition scholars is that attention / interpretation precedes action (Cowan, 1986; Daft & Weick, 1984; Dutton, Fahey, & Narayanan, 1983; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). To paraphrase Fiske and Taylor (1984), without attention, nothing else happens. Hambrick (1981, p 299) reiterated this view, 'executives can only act on those phenomena to which their attention is drawn.' Within the perspective of strategic choice (Child, 1972), managerial decisions, which shape organizational action, occur due to the focus of managerial attention (Ocasio, 1997; Ocasio & Joseph, 2005). Ocasio (1997) has argued that the generating and focusing of managerial attention is a central role of the firm. However, relatively few studies have examined the impact of managerial attention on firm innovation (Eggers & Kaplan, 2008; Kaplan et al., 2003; Yadav et al., 2007) with no studies focused on exploratory innovation. Given the theoretical importance of managerial attention to the exploration of new knowledge, this is a significant gap in the innovation literature. The lack of focus on managerial attention has not gone unnoticed. Hutzschenreuter and Kleindienst (2006) in a recent review of the strategy process literature pointed out:

> '…current research falls short in addressing the question of how decision makers decide on what to decide and how decision makers' attention is channeled and distributed within an organization…we strongly believe that strategy-process research would greatly benefit from exploring this question…Why do firms attend to some issues but not others?

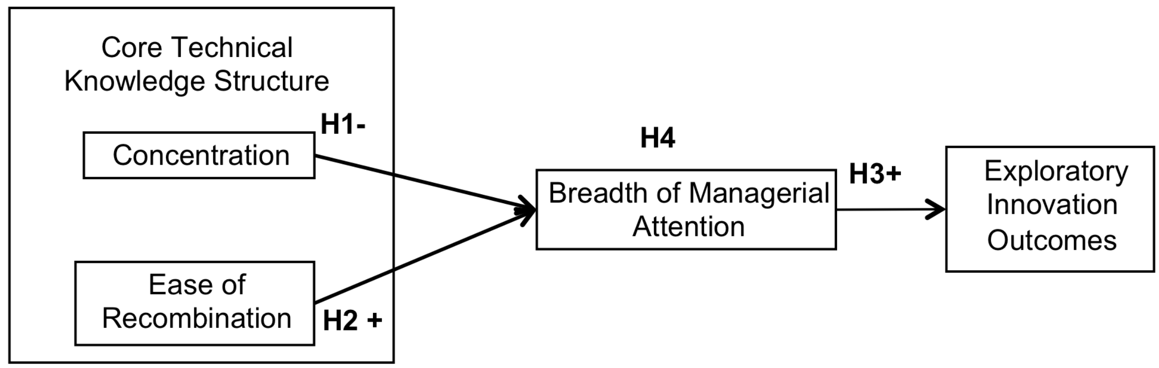
> Why do issues get attention in some firms but not in others?'... 'What are the forces that shape a firm's strategic agenda?' (2006, 708).

Ocasio (1997) hypothesized that a firm's unique resources would be an important influence on managerial attention but this question remains unexamined and leads to the research question: What is the influence of a firm's core technical knowledge structure on managerial attention? Further, while a firm's unique technical resource position and managerial attention have both been found important to firm innovation, the lack of joint consideration of these constructs is a gap in the technical innovation literature which leads to the research question: What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes?

The absorptive capacity, cognition and search literatures provide a theory base to examine these questions (Brewer & Treyens, 1981; Cohen & Levinthal, 1990; Cyert & March, 1963; Lyles & Schwenk, 1992; March & Simon, 1958a; Rumelhart, 1980 ; Zahra & George, 2002). These literatures suggests that management's interaction with the core technical knowledge portfolio and its characteristics will impact the mental models senior managers use to understand the organizations capabilities and its environment. This theory base provides a reason to believe that the structure of the firm's core technical knowledge portfolio will influence managerial attention and that the breadth of managerial attention will mediate the relationship between the firm's core technical knowledge and exploratory innovation outcomes.

1.1 Overview of the Research Model

The theoretical model is presented in Figure 1. The absorptive capacity (Zahra & George, 2002), cognition (Lyles & Schwenk, 1992) and capability development (Helfat & Peteraf, 2003) literatures suggests that management's engagement with the structure in a firm's core technological knowledge should affect the breadth of managerial attention. For a high technology firm, the resource and knowledge based literatures emphasize the importance of structure in a firm's core technical knowledge on its innovative outcomes (e.g. Barney, 1991; Fleming & Sorenson, 2001; Grant, 1996; Prahalad & Hamel, 1990; Wu & Shanley, 2008). However, the absorptive capacity and innovation literatures suggests that managerial cognition plays an important role in the identification of new information available for recombination with the firm's core technical portfolio (e.g. Bantel & Jackson, 1989; DeTienne & Koberg, 2002; Zahra & George, 2002). Managerial attention is the first step in the cognitive processing model (e.g. Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983) and should effect the identification of new information available for recombination, mediating the resources structure - exploratory innovation relationship.



Research Model

Figure 1.1

1.2 Theoretical Contributions

This dissertation will advance knowledge about exploratory innovation by drawing together two main themes in innovation research, Core Technical Knowledge Structure and managerial cognition (Breadth of Managerial Attention) into a single model. By examining core technical knowledge structural characteristics that affect the Breadth of Managerial Attention, this dissertation will seek mechanisms and their interactions that lead to or encumber exploratory innovation. It is likely that this research will add to the resource based, cognition and innovation literatures by commenting on 1) the effect of resource structure on managerial attention and 2) the influence of managerial attention firm level exploratory innovation.

1.3 Dissertation Structure

Chapter 2 presents a brief overview of the research that has focused on the role of exploration and exploitation on innovation. The role of managerial cognition and firm resources are explored within this framework. Further depth is presented regarding managerial attention and resource structure. Gaps in strategy research focusing on managerial attention are identified and the above-mentioned research questions are more fully developed. Chapter 3 further develops the research model and hypotheses. Chapter 4 discusses the proposed methodology of the study, including data collection procedures, characteristics of the target sample, measures that will be used to assess the constructs, and the statistical techniques that will be used for data analysis. Chapter 5 presents the results of the study. Chapter 6 discusses and integrates the major findings of the study while focusing on the contributions made to the literature. This chapter also discusses the limitations of the study and suggests areas for future research.

2. LITERATURE REVIEW

2.1 Introduction

Technical innovation is a central concept to theories of economic growth (Schumpeter, 1934). Managerial cognition (e.g. Barringer & Bluedorn, 1999; Damanpour & Schneider, 2006; Yadav et al., 2007) and organizational resources (e.g. Fleming, 2001; George, Zheng, & Kotha, 2007; Hall et al., 2001; Henderson & Cockburn, 1994; Henderson & Cockburn, 1996; Lin, Chen, & Wu, 2006, Fleming, 2001 #1311; Patel & Pavitt, 1997; Trajtenberg, Henderson, & Jaffe, 1997) are two major factors found to influence technical innovation. The importance of these factors comes from the epistemological perspective that innovation originates in the recombination of existing elements along with the potential introduction of new elements (Hargadon & Sutton, 1997; Henderson & Clark, 1990; Schumpeter, 1939).

The recombination / introduction process is constrained by the firm's current knowledge and resources available for recombination and the localness of search for new knowledge and resources (Fleming, 2001). The localness of search is a cognitively influenced process (Cohen & Levinthal, 1990; Cyert & March, 1963; March & Simon, 1958a; Winter, 2000; Winter et al., 2007). Although attention is the initiating stage of that process (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980) that would drive non-local search, the influence of attention on exploratory innovation remains un-examined. Ocasio (1997) hypothesized that a firm's unique resources would be an important influence on managerial attention but this hypothesis remains unexamined.

A firm's unique technical resource position and managerial attention are both theoretically important to firm exploratory innovation. The lack of joint consideration of these constructs is a gap in the technical innovation literature that leads to the following research questions: What is the influence of a firm's core technical knowledge structure on managerial attention? And, What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes? This research answer calls for greater examination of the role and consequences of managerial attention (Hutzschenreuter & Kleindienst, 2006).

In order to place these research questions in proper relief, the following addresses three literatures and their influence on innovation. First the influence of firm exploitation and exploration is briefly reviewed. Second, the role of managerial cognition on innovation is examined. Senior management attention is identified as an important under studied construct in innovation research. Subsequently, the broader area of attention research is reviewed in greater depth and a firm's resources are identified as a theoretically important but unexamined influence on managerial attention. To further explore the role of heterogeneous resources, the third part of this literature review concentrates on the role of a firm's existing resources on innovation as the elements that are recombined in the innovation process. The influence of Concentration and the Ease of Recombination, as measures of the structure of the firm's core technical resource portfolio are focused upon.

2.2 Exploration and Exploitation

Research into innovation has a substantial history of examining the effect of search on innovation outcomes (e.g. Dosi, 1988; Fleming & Sorenson, 2004; Stuart & Podolny, 1996; Teece, 1988). Local search refers to the exploration of technical knowledge that is closely related to a firm's current technical knowledge base (Stuart & Podolny, 1996). Local search, commonly referred to as exploitation, is the predominant search pattern in innovation research (Cyert & March, 1963; March & Simon, 1958a; Nelson & Winter, 1982; Stuart & Podolny, 1996). Exploitation concentrates on the refinement and extension of exiting competencies and technologies aiming for returns that are predictable (March, 1991). Local search constrains the direction of corporate innovation to areas that are near the firm's current technological base (e.g. Dosi, 1988; Stuart & Podolny, 1996).

Local search results from individual and organizational processes. At the individual level, local search is the result of the bounded rationality of decision makers who are prone to base future R&D decisions on the firm's historic R&D activities (Nelson & Winter, 1982; Stuart & Podolny, 1996). At the organizational level, the operating of routines facilitate local search (Cyert & March, 1963; Nelson & Winter, 1982; Stuart & Podolny, 1996). Organizational learning and competency research posit that a firm has a higher likelihood of innovative success if it develops experience by concentrating knowledge generation in areas where it has already developed prior knowledge (Cohen & Levinthal, 1990). These individual and organizational processes closely link a firm's core technical knowledge structure and its innovative outcomes through the function of local search.

Organizational routines often become more ingrained as firm's age (Hannan & Freeman, 1984). Research on firm age and innovation have found that while overall innovation levels increase as firms age, those innovations are more likely to be incremental extensions of the firm's historic technological domain (Katila & Ahuja, 2002; March, 1991) and less innovative than younger firms (Sorensen & Stuart, 2000). Concentrating on familiar technologies can preclude the identification of useful technologies that may be technologically distant or such concentration may exhaust the set of useful combinatorial possibilities (Fleming & Sorenson, 2001). The technological focus that allows a firm to develop a distinctive competence may lead to a 'core rigidity' (Leonard-Barton, 1992), a 'competency trap' (Levitt & March, 1988), a 'familiarity trap', a 'maturity trap' or a 'propinquity trap' (Ahuja & Lampert, 2001).

As opposed to exploitation, exploration is search that is experimental with returns that are uncertain (March, 1991). Exploratory search by definition extends beyond some component of the firm's boundaries. Research has focused on the impact of exploration that crosses technological and organizational boundaries (e.g. Ahuja & Katila, 2004; Ahuja & Lampert, 2001; George et al., 2007; Rosenkopf & Nerkar, 2001). Ahuja and Lampert (2001) found that branching into new technological domains may help mature firms avoid the risks to innovation outcomes, due to firm aging. Rosenkopf and Nerkar (2001) found that firms which explore outside the firm's technological or organizational boundaries increase the overall impact of their innovative activities. Ahuja and Katila (2004) found that increased science and geography search across firm boundaries increased innovative output. George, Zheng and Kotha, (2008) found that when younger firms jump to new technological domains the quantity and quality of the firm's innovative output increased.

The processes that initiate exploratory search are different from those that perpetuate local search. Ahuja and Katila (2004) found, in a study of path creating search, that technical exhaustion and geographic expansion were two triggers that initiated exploratory search and subsequent innovation. However, Ahuja and Katila (2004) do not address the mechanisms, within the firm, which link technical exhaustion and geographic expansion to exploratory search. Chen and Miller (2007) more directly address this mechanism in their study of the determinants of R&D search intensity. In this study, aspiration level triggers (Greve, 1998; Lant et al., 1992) are the situational elements that impact organization level R&D expenditures. Chen and Miller (2007) base their study on Ocasio's (1997) underlying work on the attention based view of the firm and the impact of aspiration failure on managerial attention (Greve, 1998; Lant et al., 1992). Chen and Miller (2007) find that aspiration level failure promotes R&D search. Local search clearly ties a firm's core technical knowledge to its innovative outcomes. However, exploratory search is initiated by mechanisms that operate through managerial attention (Chen & Miller, 2007; Ocasio, 1997). Only a few studies were found which focused on the relationship of managerial attention and firm innovation (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007) and none of these studies examined exploratory innovation outcomes. This gap in the innovation literature leads to the research question: What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes? In order to develop this research question more thoroughly, the literature on managerial cognition and attention is examined in greater depth.

2.3 Senior Management Cognition

Senior managers are important decision makers who influence organizational innovation by bridging the internal and external environments (Child, 1972), accessing external information (Rodan & Galunic, 2004; Smith, Collins, & Clark, 2005), championing technologies (Howell & Higgins, 1990), directing internal resources (Barker & Mueller, 2002) and creating and supporting an innovative culture (Bantel & Jackson, 1989; Damanpour & Schneider, 2006; Elenkov, Judge, & Wright, 2005; West & Anderson, 1996). Managerial cognition is an important antecedent of these managerial actions (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Unlike routine decisions, in strategic decisions (Child, 1972) such as exploratory innovation, the role of managerial cognition is emphasized (Bantel & Jackson, 1989; Cyert & March, 1963; Hambrick & Mason, 1984; March & Simon, 1958b).

Early research examining the impact of managerial cognition on innovation focused on survey and interview methods to measure cognitive variables (e.g. Daft, 1978; Dewar & Dutton, 1986; Hage & Dewar, 1973; Kimberly & Evanisko, 1981). Difficulties in collecting this information at the executive level in conjunction with Hambrick and Mason's (1984) reasoning regarding demographic characteristics, led to a focus on observable demographics as the principal method of measuring executive level cognitive effects on innovation (e.g. Bantel & Jackson, 1989; Barker & Mueller, 2002; Daellenbach, McCarthy, & Schoenecker, 1999; Damanpour, 1991; Damanpour & Schneider, 2006; DeTienne & Koberg, 2002; Elenkov et al., 2005; Kimberly & Evanisko, 1981; Smith et al., 2005; Wolfe, 1994). Results of demographic studies on innovation have been inconsistent with innovation scholars shifting their focus to managerial attention. The following studies have specifically focused on the impact of senior manager attention on firm innovation; Kaplan (2008), Eggers and Kaplan (2008) and Yadav, Prabhu and Chandy (2007).

Kaplan (2008) used a longitudinal analysis of patenting behavior in the telecommunications industry to examine the effect of senior manager attention when an industry is experiencing the introduction of radical technology, fiber optics. Senior manager attention was operationalized using a count of the 'optical' words in the shareholders letter in the annual report. Prior senior manager attention to optics significantly impacted a firm's later patenting behavior. The effect of senior manager attention was robust to controls for a firm's customer focus as well as its capabilities. Senior manager attention also interacted with incentives and capabilities. Senior manager attention was found to be more important to increased optical patenting when there were low incentives or low capabilities. Importantly, senior manager attention was robust to controls for senior manager demographics indicating senior manager attention was a construct independent of managerial demographics. Also set in the telecommunications industry, Eggers and Kaplan (2008) studied fiber optics as evidence of radical technology adoption. Senior manager attention was measured using the shareholders letter in the annual report. Senior manager attention sped entry into a new product market when it was directed toward the emerging technology and slowed entry when directed toward the existing technology. Yadav et al (2007) used the banking industry and the advent of internet banking to examine the effect of senior manager attention on technical innovation. They found that senior manager attention to the future as well as the internal and external environment influenced the speed of detection and speed of development of internet banking. Senior manager attention to the future was also influential on the breadth of deployment of internet banking.

These three studies collectively find senior manager attention an important antecedent of firm level innovation. However, there are important gaps in this research. First, the importance of a firms' existing core knowledge portfolio on innovation is left out. Kaplan (2008) does include a measure of a firm's existing optical capability, measured as the number of years the firm has had an optical product in the market. However, this does not address the role of core knowledge structure an important influence on innovation (Fleming, 2001). Second, while some research has addressed the relationship of managerial attention of a firm's innovation outcomes, this research has focused on innovation adoption and not specifically addressed exploratory innovation outcomes.

There is general agreement in the larger body of strategy literature regarding the importance of managerial cognition. There is similar agreement within the technical innovation literature that senior management cognition is influential on firm level innovation. Measures of managerial cognition have focused on demographics but results have been inconsistent and criticized as imperfect measures of underlying cognitive processes. Since cognition plays a critical role in innovation, it is surprising that the role of 'attention' as the initiating step of the cognitive processing model remains largely unexplored for its effect on firm level exploratory innovation. Only three studies were identified which examined the influence of senior management attention on firm level adoption of innovation, none of which addressed exploratory innovation. Given the wide body of study on innovation and the importance placed on managerial cognition on innovation, the relative lack of study of senior management attention is a gap in the innovation literature. To more fully explore the role of attention on innovation, the following section examines the wider body of literature on attention.

2.4 Attention in Psychological Research

Attention has a long history of research within psychology. As early as the 1800's, researchers focused on attention as a field of study. However, it was not until the cognitive revolution in the 1950's, as a response to behaviorism, that modern research on attention began. This research focused on how voluntary control and subjective experience arise from and regulate individual behavior (Posner & Rothbart, 2007). An overarching view traditionally put forth to explain attention is a top down perspective which views attention as a goal driven process filled with individual agency and initiated by higher level processing. This perspective is concerned with the role of the mind on attention. By 'mind', cognitive psychologists refer to the cognitive structures and processes individuals rely on to shape their understanding of experience. Mental schemas are central to cognitive psychology as they are the 'theories or concepts that guide how people take in, remember and make inferences about raw data' (Fiske & Taylor, 1984, p140). The top down perspective and the influence of the cognitive revolution can be found in the work of organizational scholars writing within the Carnegie School (e.g. Cyert & March, 1963; Gavetti, 2005; Gavetti, Levinthal, & Ocasio, 2007; March & Simon, 1958a; Simon, 1947). The following section reviews attention research conducted within organizational scholarship.

2.4.1 The Origins of Attention Research in Organizational Scholarship

The importance of attention in organizational research is rooted in the ground breaking work of Herbert Simon (1947), James March (1958a) and Richard Cyert (1963). Collectively, these works criticized the assumption, of earlier management theorists, that actors in organizations were economically rational agents only motivated by economic self-interest, completely informed of all available alternatives. Simon replaced the assumption of an 'economic man' with that of an 'administrative man'. While an administrative man pursued his own self interests, inherent cognitive limitations meant that, he was only aware of a few of the possible alternatives available. This idea is encapsulated in the idea of 'bounded rationality' (Simon, 1947). In selecting alternatives, administrative man was more likely to choose paths that appeared to reach a satisfactory conclusion as opposed to an optimal one. The idea of 'satisficing' behavior incorporated the concept of bounded rationality and more directly challenged the assumption of an 'economic man' (Simon, 1955). As the assumption of economic rationality was replaced, individual decision-making became an important research question with scholars focusing on influences that affected search and choice dynamics. Two streams of research, focused alternatively at the individual and the organization addressed aspects of this issue.

At the individual level, scholars interested in the cognitive influence on decision making focused on the influence of cognitive knowledge representations (Huff, 1990). These representations were important within the Carenige school for the impact they implied on environmental understanding and decision making (Cyert & March, 1963; March & Simon, 1958a). Given limited information processing capacity, cognitive knowledge representations facilitate human functioning in information environments that are munificent, complex and ambiguous. (Schwenk, 1984; Simon, 1947; Sproull, 1984; Starbuck & Milliken, 1988). By organizing the information environment, knowledge representations facilitate information processing and decision-making by providing a basis for information evaluation, thus improving cognitive economy (Walsh, 1995). The structural dimensions of these knowledge representations have been found to influence knowledge acquisition (Carley & Palmquist, 1992), firm geographic scope (Calori, Johnson, & Sarnin, 1994), team performance (Carley, 1997), firm performance (McNamara, Luce, & Tompson, 2002; Nadkarni & Narayanan, 2007) and strategic persistence (Nadkarni & Narayanan, 2007).

Also originating from the Carnegie school, but focused at the organizational level, the role of routine (Nelson & Winter, 1982) and the influence of organizational structure (Ocasio, 1997) have been studied for their impacts on attention, decision-making and action. Research into organizational routines and structure take different views of individual agency. Scholarship focused on routines downplays the role of managerial attention and individual agency whereas scholarship focused on organizational structure emphasizes it. Organizational routines are theorized to adapt incrementally in response to performance feedback and local search activities, with alternatives drawn from local possibilities and evaluated against a satisfycing criteria (Levitt & March, 1988). This process emphasizes a feedback / habit form of learning that is, largely non cognitive. It is also at the heart of a significant body of research on organizational learning (Gavetti et al., 2007). However, as Gavetti and Levintal (2000) demonstrate, the cognitive representations of decision makers should not be left out of the equation as they significantly impact both the sampling and evaluation of decision alternatives. The lack of attention in routine based learning to individual agency has been criticized (Gavetti et al., 2007). Some scholars are seeking to integrate the two logics of 1) non cognitive feedback / habit based learning and 2) cognitive rational anticipation (Gavetti & Levinthal, 2000; Winter et al., 2007).

In addition to the influence of organizational routines, scholars have focused on the influence of the organization's structures (Ocasio, 1997) in directing attention. In a theory article, Ocasio (1997) sought to recapture the Carnegie school's original dual emphasis on cognition and structure. Ocasio (1997) believed that scholarship focused on routine based learning had not sufficiently addressed Simon's (1947) dual emphasis on cognition and structure as it effects the attention of organizational decision makers. The guiding premises of Ocasio's (1997) view of the firm is that; 1) Managerial action is dependent upon managerial attention (focus of attention), 2) Managerial attention depends upon the situation the manager finds themselves in (situated attention) and 3) The situation and how the manager attends to it depends on the firm's rules, resources and social relationships (structural distribution of attention).

In summary, the Carnegie school's influence on organizational research is profound. This research was aimed at both the individual and the organizational level. At the individual level, this research presents a view of decision makers being influenced by underlying knowledge structures that impact interpretation. At the organizational level, routines and structures influence managerial attention. Action based upon that attention has been seen as both intentional and automatic. With this general background on the origins of attention research in organizational studies, I now turn to a more specific examination of the definition of attention and then the treatment of attention within strategy and innovation research.

2.4.2 Definitions of Attention

Within organizational research focused on cognition, scholars have proposed a staged information-processing model of attention, interpretation and action (Daft & Weick, 1984; Dutton et al., 1983; Dutton & Jackson, 1987; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Fiske and Taylor (1984) define attention as that which occupies the consciousness. This definition separates attention from interpretation in the information-processing model. Sproull (1984, p10) takes a different approach in arguing that attention incorporates the entire information processing sequence. He defines attention as 'allocating information-processing capacity (receiving, cognitive processing, disseminating) to environmental stimuli over time.' Ocasio (1997) argues that although attention and interpretation can be conceptually separated, they are so interrelated that any distinction is not meaningfully important. Ocasio (1997) argues that this interpretation of attention is more in line with the original cognitive perspective of the Carnegie school. He writes;

> 'Simon and Weick's respective concepts of decision premises and enacted environments refer to how organizational decision makers encode information, and both concepts' (attention and encoding) 'were considered as central parts of organizational attention' (Ocasio, 1997, p189).

Agreeing with this logic, attention herein is defined in line with the definition set forth by Ocasio (1997, p 189).

> 'Attention is 'the noticing, encoding, interpreting and focusing of time and effort by organizational decision-makers on both (a) issues: the available repertoire of categories for making sense of the environment; and (b) answers; the available repertoire of action alternatives.'

Table 2.1 includes the primary definitions of attention used in organizational studies literature. The following sections examine the antecedents and consequences of managerial attention applied in the strategic management literature. Table 2.4 summarizes the 'antecedents vs consequences' focus of the empirical strategy research on managerial attention.

2.4.3 Attention Within Strategy Research

While attention is a central element to a wide body of organizational scholarship, it is often implied and not directly discussed. Ocasio (1997) noted this gap in the literature and in a theory article more directly addressed the importance of managerial attention in developing an 'attention based' view of the firm. Ocasio believed that organizational research had not effectively dealt with the importance of managerial attention and the dual emphasis on cognition and structure in Simon's (1947) original work. The guiding premises of Ocasio's (1997) view of the firm is that managerial action is dependent upon managerial attention which is influenced by the situation the manager finds themselves in and the way the firm's rules, resources and social relationships direct attention. Ocasio's propositions focused on the internal structural elements of the firm and did not address either the 1) cognitive predispositions of the dominant coalition or the 2) influence of the environmental context on managerial attention. Ocasio's (1997) article had the effect of focusing attention research. The following reviews the theoretical and empirical strategy literature that explicitly addresses managerial attention. The review is organized to focus first on the antecedents and second the consequences of managerial attention.

2.4.4 Antecedents of Managerial Attention

Research within strategy literature has broadly focused on four areas as antecedents that influence managerial attention. These are 1) cognitive dispositions of top managers, 2) the organization's contextual / structural elements, 3) environmental contexts and 4) specific mechanisms that initiate managerial attention. Each area is dealt with in turn. Table 2 and 3 summarizes the relevant theoretical and empirical literature on managerial attention, respectively.

Cognitive Dispositions that Direct Managerial Attention

The role of top managers has a long history of examination within management literature (e.g. Barnard, 1938; Penrose, 1959). Top managers must identify and interpret strategic issues, (Dutton et al., 1983; Dutton & Jackson, 1987) decide on strategic choices and take action. The dominant process model for managerial cognition researchers is that managers engage in an information processing sequence of Attention, Interpretation and Action (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Dutton & Jackson, 1987; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Underlying this process are the limited attentional and cognitive capabilities of managers (Cyert & March, 1963; March & Simon, 1958a; Simon, 1947) who are often beset by high levels of information flows (e.g.Mintzberg, 1973) and are operating in an indeterminate environment. Within such an environment and due to their cognitive constraints and predispositions, managers ignore certain information while attending to others (Sproull, 1984).

In such contexts, decision makers automatically and unconsciously reduce the cognitive demands of the situation by resorting to simplified models of reality they have built through experience over time (March & Simon, 1958a). Utilizing this premise, organizational researchers within the Carnegie School (Cyert & March, 1963; March & Simon, 1958a; Simon, 1947) emphasize the roles of bounded rationality, limited cognitive processing capacity and selective perception on organizational decision-making.

Hambrick and Mason's (1984) upper echelon perspective (UEP) specifically applied the Carnegie school's emphasis on human cognition and decision making to strategic managers and the dominant coalition. In this view, top executives are fundamentally responsible for directing the organization. Managerial cognition is a central tenant of the upper echelon perspective. As Hambrick notes (1984, p 193), 'organizational outcomes – both strategies and effectiveness – are viewed as reflections of the values and cognitive bases of powerful actors.' The cognitive perspective inherent in the UEP has primarily been operationalized through the use of demographic measures as indicators of cognitive predispositions. As Hamrick (1984, p 196) writes, observable characteristics are 'indicators of the givens that a manager brings to an administrative situation.' While the relationship between the senior management, strategic choices and firm performance is central to business strategy research, the use of demographic indicators has been criticized as poor surrogates for cognitive constructs. Demographic characteristics are not the theoretical drivers of strategic processes and choices. Instead, they are proxies for the cognitions, values and perceptions that effect strategic choice. Priem, Lyon and Dess (1999) as well as Carpenter et al (2004) have called for greater focus on senior management processes and judgments in order to improve the understanding of top managers and the impact of their choices.

The process model of managerial cognition indicates that managerial attention precedes managerial action (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Dutton & Jackson, 1987; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Thus, managerial attention has been proposed as an explanation for the types of relationships identified in UEP research. However, only one study by Cho and Hambrick (2006) (discussed below) has directly addressed the relationship of senior management demographics, managerial attention and firm actions (innovation adoption). A second study by Kaplan (2008) (discussed below) used senior management demographics as controls in an attention study and has implications here.

Cho and Hambrick (2006) focused on senior management attention and applied agency theory to ask the research question; How do senior management demographics and incentives combine to effect managerial attention and entrepreneurial strategy? Using 30 US airlines operating from 1973-1986 they examined the change in senior management's 'attentional orientation' due to deregulation. Management's entrepreneurial orientation vs their engineering orientation was measured by examining changes in the concentration of entrepreneurial and engineering words in the annual letter to shareholders before and after deregulation. Entrepreneurial strategy was measured by examining objective indicators of realized strategy for the airline industry such as the number of city-pairs served. They found that deregulation precipitated a general shift from an 'engineering' focus to an 'entrepreneurial' focus. Further, these attentional changes were significantly related to a change in senior management demographics and change in compensation / incentive structure. Regarding the senior management composition variables, industry tenure, change in output orientation, change in industry tenure heterogeneity and change in functional heterogeneity were all related to the attention variable. The authors also tested for a mediating effect of attentional changes between the composition / compensation change variables and realized entrepreneurial strategy. Change in managerial attention was found to partially mediate between change in senior management composition / compensation and entrepreneurial strategy. The authors write 'changing the composition or compensation of a senior management will tend to bring about a change in managerial attention, which in turn contributes substantially to bringing about changes in strategy' (Cho, 2006 p 464).

The Cho and Hambrick (2006) study adds to our understanding of managerial attention in a few important ways. First, change in specific senior management demographics was demonstrated as an adaptive mechanism that shifts managerial attention. Second, managerial attention was demonstrated to be sensitive to other organizational variables (compensation incentives). Third, changes in managerial attention partially mediated the relationship between senior management characteristics and realized strategy. This third point reinforces the belief that managerial attention influences firm actions/outcomes separately. Further, this third point indicates that senior management characteristics and managerial attention may be considered separate constructs. This last point is supported by Kaplan (2008), which will be reviewed in depth later, who used senior management demographics as a control variable. She found 'the inclusion of measures of senior management demographics does not eliminate the effect of senior management attention suggesting that these are separate constructs' (2008, p 27).

While Cho and Hambrick (2006) adds to our understanding of the role of cognitive dispositions (senior management characteristics) on managerial attention and strategic action, there are gaps in this research. First, the study concentrated on changes in senior management demographics as an adaptive mechanism that drives changes in senior management attention. By focusing on change variables, our understanding of attention in organizations not undergoing such changes is not addressed. Second, the sample is limited to large established companies so our understanding of managerial attention in young and adolescent firms is not addressed. Third, the study was conducted using the context of deregulation. Thus, the impact of managerial attention in an environment without a destabilizing shock is unexamined. These gaps partially motivate the current research.

Internal Contextual Influences on Managerial Attention

The preceding section addressed the role of top management's cognitive dispositions on managerial attention. Within that research, management turnover and incentives (Cho & Hambrick, 2006), had an effect on managerial attention. This section more explicitly addresses the role of organizational contextual influences on managerial attention. Ocasio's (1997) attention based theory of the firm focused on the influence of the firm's internal structure on managerial attention. The principles of this view are that; 1) Managerial action is dependent upon managerial attention (focus of attention), 2) Managerial attention depends upon the situation the manger finds themselves in (situated attention) and 3) The situation and how the manager attends to it depends on the firm's rules, resources and social relationships (structural distribution of attention). Some research has addressed the impact of social relationships and rules on managerial attention. However, no research has addressed the impact of resources on managerial attention. Ocasio and Joseph

(2005) extended Ocasio's (1997) work on attention and the internal structural elements of the firm to develop, in a theory article, linkages between internal organizational structures, managerial attention and strategy processes.

With respect to Ocasio's (1997) point regarding the influence of social relationship of managerial attention, Sproull (1984) studied seven public sector managers over 29 days and used their time allocation to study attention patterns. He found that decision relevant information was identified by redundancy of transmission, deadlines and communication by trusted parties. The identification of decision relevant information through communication by trusted parties supports Ocasio's (1997) point regarding the social relationship aspect of managerial attention. At the intra-organizational level but also building on the social aspect of attention, Howard-Grenville (2006) sought to answer the research question, what is the impact of multiple subcultures on the interpretation of and action on environmental issues? She conducted a nine-month ethnographic study of a single computer chip maker's response to environmental issues arising out of a new manufacturing process. This study found that power differentials between subcultures influences organizational attention, issue interpretation and strategy adoption. Thus, from a theory perspective as well as two empirical articles, social context is important in directing managerial attention.

Ocasio's (1997) point regarding the influence of a firm's rules on managerial attention has also been supported. Sproull's (1984) conclusion that decision relevant information is sometimes identified by transmission redundancy supports this position. March, Schulz and Zhou (2000) examine the influence of formalized structure on managerial attention when they ask the research question: How does formalized attention impact organizational stability and adaptation over time? Using Stanford University as a research setting, this study examined the minutes from the 108-year history of that university's Academic Council and the 31-year history of its Faculty Senate. Formal attention was operationalized by the presence of agenda items presented in formal meetings. The effect of this formal attention was measured through its impact on rule adoption and rule alteration. The study found that formalized attention (agenda items) of decision makers in a given area is associated with creation and change (of Academic Council and Faculty Senate rules) in that same area. Further commenting on the role of organizational rules on managerial attention, the previously mentioned study by Cho and Hambrick (2006) found that attentional changes were more significant when they were accompanied by changes in the incentive structure of the top management team. These studies collectively support Ocasio's (1997) position that organizational rules influence managerial attention.

Ocasio's (1997) attention based view of the firm indicated that a firm's rules, resources and social relationships influence managerial attention. Some empirical support was found for the importance of a firm's rules and it's social relationships on managerial attention. However, Ocasio specifically identifies a firm's resources as important to the 'Structural Distribution of Attention.' Ocasio writes 'The schemas used by organizational decision makers to characterize and describe existing resources are part of the repertoire of action alternative considered' (1997, p 198).

While noting the importance of a firm's resources on managerial attention this idea is not developed further. Also, none of the studies identified through the literature review addressed the importance of a firm's resources on managerial attention, a significant gap in the attention research.

This section has addressed the influence of internal contextual variables on managerial attention. The lack of research addressing the influence of a firm's resources on managerial attention is a significant gap, especially in light of the theoretical attention paid to resources (Barney, 1991; Barney & Arikan, 2001; Ocasio, 1997) and the importance of a firm's core technical knowledge on innovation outcomes (e.g. Fleming, 2001; George et al., 2007; Hall et al., 2001; Henderson & Cockburn, 1994; Henderson & Cockburn, 1996; Lin et al., 2006; Patel & Pavitt, 1997; Trajtenberg et al., 1997).

External Contextual Influences on Managerial Attention

Organizational adaptation to changing environments is a central question in strategy literature (Astley & de Ven, 1983). Given this, it is natural that the influence of external contextual variables on managerial attention has been an area of research. Abrahamson and Hambrick (1997) examined the influence of differences in managerial discretion across industries on managerial attention. Managerial discretion is defined as the 'latitude of actions' available to managers as constrained by their own awareness, their repertoires and the unstated constraints of the industry (Hambrick & Finkelstein, 1987). Attention measures were collected from the letter to shareholders in the firm's annual reports from 1985-1989. 14

industries that differed widely in managerial discretion were examined for intra-industry attentional homogeneity. Attentional homogeneity was defined as the 'degree of similarity in the foci of attention of top managers across organizations' (1997, 514). Measures were implemented using computer assisted text analysis at the word level. Specifically, homogeneity was calculated as the degree to which each company's annual letter used the same words with equal frequency as other organization's letters in the same industry. Abrahamson and Hambrick (1997, p 527) found that 'industry level discretion has a strong and significant effect on attentional homogeneity.'

Cho and Hambrick (2006), discussed above, examined the impact of senior management composition changes and incentive structures on managerial attention during a period of deregulation for the airline industry. The authors argued that deregulation created a new freedom for executives in terms of their product market discretion. Thus deregulation in the airline industry represented an increase in managerial discretion (Hambrick & Finkelstein, 1987). As part of this study, industry level entrepreneurial attention was measured before and after the deregulation period. For the airline industry, entrepreneurial attention increased from 0.32 prior to the deregulation (1973-1978) to 0.68 after the deregulation (1979-1984). This change calculated at t-value of 1.59 for a significance of $p < 0.01$. Thus both Abrahamson and Hambrick (1997) and Cho and Hambrick (2006) found that managerial discretion or industry level events that increase managerial discretion influence managerial attention.

Nadkarni and Barr (2007) also sought to examine the influence of an organizations' environmental context on managerial attention. However, instead of focusing on the level of managerial discretion, the impact of high velocity environments was examined. Four industries were analyzed in two matched pairs, semi conductors and cosmetics categorized as high velocity and aircraft and petrochemicals categorized as low velocity. Managerial 'attention focus' was defined as attention directed to the task sector and attention directed to the general sector of the environment. The task sector includes environmental elements that have direct transactions with the firm such as competitors, suppliers and customers. The general sector includes more macro-level elements such as demographic , economic and political elements (Daft, Sormunen, & Parks, 1988; Garg, Walters, & Priem, 2003). Attention focus was measured by using management's annual letter to shareholders to create causal maps of managerial cognition. Measures of centrality were applied to the task and general sectors of the maps and used to estimate managerial attention focus on the task and general sectors. Nadkarni and Barr (2007) found that higher velocity environments were associated with greater managerial attention to the task sector as opposed to the general sector. Also, increased managerial attention to the task sector speeded strategic actions in response to changes in the task sector. Strategic actions were developed through analysis of secondary sources such as 10k reports, industry reports and newspapers. The speed of strategic action was measured as the number of days between the occurrence of an environmental event and the initiation of a strategic action. Tests of mediation found that managerial attention mediated the relationship between the high velocity environment and the speed of strategic actions.

While Nadkarni and Barr (2007) did not directly examine managerial discretion, there is a good deal of commonality in the descriptions of environments with high managerial discretion and environments considered high velocity. As Nadkarni and Barr write: 'High velocity industries are characterized by rapid and unpredictable change in product and process technologies and competitors' strategic actions…' (2007 p 9). The ability of managers to offer unpredictable products, utilize different process technologies and engage in different strategic actions describes an environment with high managerial discretion, defined as 'latitude of action' (Hambrick & Finkelstein, 1987). Abrahamson and Hambrick (1997), Cho and Hambrick (2006) and Nadkarni and Barr (2007) collectively addressed the research question: Does the firm's environment affect managerial attention? They found that the level of managerial discretion affected managerial attention. While not directly examining the role of the environment on managerial attention, Eggers and Kaplan (2008) and Kaplan (2008) both set their studies in contexts of revolutionary change to explore the impact of managerial attention. In these studies, the external environment has been directly examined and indirectly implied in the study of managerial attention. Collectively, these studies present a picture of industry level environmental change impacting the generalized level of managerial discretion, which creates the opportunity for increased heterogeneity in managerial attention. While, specific focuses of managerial attention mediate the relationship between environmental change and organizational action/outcomes.

The prior studies implicitly assume a perspective in which the organization is, unattached to but affected by changes in the organizational environment. However, organizations can be understood as existing with various degrees of attachment to the organizational environment (Scott, 1981 (1992)). Only one study was found that examined the effect on managerial attention of the organizations attachment to the environment. Hung (2005) examined this research question; How does a firm's attachment to the environment influence managerial attention? To answer this question, Hung (2005) conducted a grounded analysis of the level of a firm's institutionalism and its impact on firm attention. Examining seven computer-manufacturing firms in Taiwan, the level of institutionalism was assessed by a firm's connections to the political policy systems and the business systems (market-hierarchy relationships). Using archival data sources and 50 unstructured interviews, Hung found a positive relationship between the level of organizational embeddedness and attention to the institutional environment. Further, this research found that these differences impacted strategic action as indicated by the timing of entry into the Chinese marketplace. Hung's (2005) research indicates that a firm's attachment to environmental elements can influence managerial attention. While this study points to an effect on managerial attention of environmental attachment, there are gaps in this work. This study was very limited in scope and was not conducted during the occurrence of any significant environmental change. Thus the effect of environmental attachment on managerial attention during occurrence of an environmental change remains an open question.

The preceding subsection reviewed studies examining the influence of the external environmental context on managerial attention. These studies indicate that 1) a firm's environmental context, with specific focus on discretion, influences managerial attention, 2) differences in managerial attention at the firm level influence the effect of environmental change on firm actions/outcomes and 3) the firm's attachment to different elements in the environment influences managerial attention and firm actions/outcomes.

Contexts used to highlight differences in managerial attention

The prior two subsections addressed the influence of internal and external variables on managerial attention. Within these reviews, the influence of environmental change is pronounced. This section more explicitly addresses the role of environmental change in managerial attention. Strategy literature deals extensively with issues of organizational adaptation to changing environmental conditions. The question of how firms behave in response to environmental change is a fundamental question in strategy research (Rumelt, Schendel, & Teece, 1994) that has profoundly influenced strategy studies focused on managerial attention. The primary context used to study managerial attention is the occurrence of an event that can be perceived as representing a risk or a threat (Dutton & Jackson, 1987; Kahneman & Tversky, 1979; Staw, Sandelands, & Dutton, 1981) and therefore requiring some level of organizational adaptation. For example, Cho and Hambrick (2006) used deregulation in the airline industry, Yu, Englemand & Van de Ven (2005) used a merger in the healthcare industry, Howard-Greenville (2006) used environmental concerns in the computer chip manufacturing industry and Kaplan (2008) and Eggers and Kaplan (2008) used the optical revolution in the telecommunications industry and Yadav (2007) used the introduction of online banking in the banking industry to examine changes in managerial attention. An alternative context was used by Nadkarni and Barr (2007) who examined the effect of high and low velocity industry contexts on differences in managerial attention. As noted above, all these contexts appear related to the level of managerial discretion. A gap in the attention literature can be identified here. By examining changes in managerial attention due to differences in environmental contexts, the ability to understand the impact of managerial attention within a context not experiencing revolutionary change is less developed.

Mechanisms that initiate managerial attention

As noted above, specific external events are often used as a context to examine changes in managerial attention. Cho and Hambrick (2006) found that turnover in the TMT is an adaptive mechanism that alters managerial attention. However, external events and TMT turnover are not the only adaptive mechanisms that alter managerial attention. Kiesler and Sproull (1982) and Gersick (1994) focused on other attention generating mechanisms. Kiesler and Sproull (1982) proposed 'aspiration level failure' as a mechanism that draws managerial attention. An aspiration level failure occurs when:

> '…managers evaluate stimuli against internal performance or aspiration criteria…. If the comparison implies results equal to or better than the aspiration level, then no problem exists. If the comparison indicates results

> worse than the aspiration level, a problem exists and problem-solving behavior will begin' (Kiesler & Sproull, 1982, p549).

The 'comparison' in the aspiration level failure formulation is most often to some historical level of performance.

Gersick (1994) examined attention generating change mechanisms in new ventures since they don't have historical levels of performance to compare to. By conducting a grounded 14-month longitudinal examination of a venture capital backed firm she identified two attention-gathering mechanisms, temporal pacing and event pacing. Temporal pacing is time related and occurred approximately half way between a project's starting date and an expected temporal milestone. The occurrence of the half way point acted as a heuristic milestone and caused organizational members to refocus and reassess their efforts. Event based pacing 'regulates people's attention through the recognition of specific events that signal when actions can or should be initiated, corrections made or endeavors considered complete' (Gersick, 1994, p41).

The mechanisms identified in the literature that generate managerial attention include; events that are perceived as risks or threats, aspiration level failures, temporal pacing and event pacing. Interestingly, the attention literature has largely focused on the occurrence of specific external events that represent implied risks or threats. This leaves open questions of how senior management attention is affected in other environments.

Summary and Synthesis of Attention Antecedents

This subsection has reviewed the strategy literature that focused on antecedents that draw and effect managerial attention. Scholars studying managerial attention have examined the impact of cognitive dispositions, organizational structure, environmental contexts, the organizational relationship to environmental elements and mechanisms that initiate managerial attention. These categories are summarized here into managerial attention influences that are external, internal and cognitive.

Our understanding of the influence of the external environmental context is the most developed. Change in the organization's environment is often used as a setting to examine managerial attention. Given the research on industry level environmental change in attention studies, the influence of managerial attention in environments not undergoing industry wide revolutionary change is under examined. With respect to the organization's internal influence on managerial attention, the role of cognitive predispositions has been empirically examined but only in a context of dominant coalition turnover (Cho & Hambrick, 2006) and as a control (Kaplan, 2008). Ocasio (1997) focused on the role of the firm's internal rules, social relationships and resources in structuring managerial attention. Of these three categories, the influence of the firm's rules (structure) has been most developed (Cho, 2006; March et al., 2000) with some work examining the influence of a firm's internal social relationship on managerial attention (Howard-Grenville, 2006; Sproull, 1984). Only the influence of a firm's resources on managerial attention has not been addressed. While Ocasio (1997) identifies a firm's resources as an important influence on managerial attention, this idea is not developed further. The role of the firm's unique heterogeneous resources in affecting managerial attention remains unexplored. This gap in the research on managerial attention is surprising given the focus in the strategy literature on the importance of a firm's unique resources (Barney, 1991; Barney et al., 2001).

The attention literature has examined elements of the three antecedent areas; external, internal and cognitive, independently. No research was identified in the literature review, which developed an integrative model of managerial attention addressing the relationship of all three elements or their relative merit in different contexts. While an integrative model is desirable, it would require greater understanding of the influences at each level and no empirical research has addressed the importance of a firm's heterogeneous resources on managerial attention. Although Ocasio (1997) set forth resources as an important influence on managerial attention, little theoretical development is included. The lack of focus in the literature to the role a firm's heterogeneous resources have on managerial attention is a significant gap, especially given the body of literature focusing on the importance of a firm's resources on firm outcomes (Barney, 1991; Barney et al., 2001) and the importance of resource structure on innovation (Fleming, 2001). The lack of research regarding the influence of a firm's core resource structure on managerial attention leads to the following research questions: What is the influence of a firm's core technical knowledge structure on managerial attention?

2.4.5 Managerial Attention, Dependent Constructs

In this literature review I have thus far concentrated on the antecedents of managerial attention. I now turn to a review of the research that addresses the impact of managerial attention. A central tenant of strategy research, in line with Child's (1972) perspective on strategic choice, is that the decisions of strategic managers matter to firm outcomes. Ocasio's (1997) attention based view of the firm builds on this perspective. He writes, 'What decision-makers do depends on what issues and answers they focus their attention on' (1997, p188). In line with the dominant process model of managerial cognition, attention impacts action and actions impact outcomes (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Dutton & Jackson, 1987; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Research on managerial attention within organizational behavior literature is roughly divided, by focus of the dependent variable, into two categories: a focus on actions and a focus on outcomes. However, these two categories are often interchangeable and difficult to always distinguish. The following reviews managerial attention studies roughly divided along these two categories. Table 2.2 and 2.3 summarizes the relevant theoretical and empirical literature on managerial attention, respectively.

Coming from an organizational behavior viewpoint, March, Schulz and Zhou (2000) and Howard-Grenville (2006) studied the impact of managerial attention on firm actions. March, et al (2000) used the agenda items from the minutes of

Stanford University's Academic Council and Faculty Senate to measure formalized organizational attention. The effect of this formal attention was measured through its impact on the adoption and change in the rules administered and used by these two academic bodies. The study found that formalized attention was associated with organizational action in the form of 'rule' creation and 'rule' change. Thus, formalized attention was associated with formalized organizational action. Howard-Grenville (2006) found a similar linkage between attention and action. In an in depth study of a single computer chip manufacturer reacting to environmental concerns, she found that power differentials between subcultures in an organization influenced organizational attention. This sub-culturally influenced attention led to the adoption of a set of strategic actions as opposed to what would have been adopted by another organizational sub culture.

Taking a more traditional strategy perspective, studies have also focused on attention-outcomes relationships. This is seen in: D'Aveni and MacMillan (1990), Levy (2005), Nadkarni and Barr (2007) and Cho and Hambrick (2006). Three studies have specifically addressed the impact of senior management attention on firm level innovation; Kaplan (2008), Eggers and Kaplan (2008) and Yadav et al (2007).

D'Aveni and MacMillan (1990) used the opposing logics of threat rigidity and prospect theory to examine the research question: What is the relationship between managerial attention to the organizational environment and firm survival? A matched pair sample of 57 failed and surviving firms in the manufacturing, retail and transportation industries was used. A sentence level coding of the annual letter to shareholders operationalized attention. Sentences were coded into pre-specified categories that identified attention to external and internal environments. This study found that failing firms paid more attention to the input and internal environment while surviving firms paid more attention to the output and external environment. Thus, the internal vs external focus of managerial attention was linked to firm survival.

Levy (2005) also used measures of internal and external attention. He asked the research question: How does managerial attention shape the global posture of the firm? He measured managerial attention through a content analysis of the annual letter to shareholders of 69 firms in three technologically intensive industries from 1987 to 1994. The letters were coded at the sentence level into predetermined categories that were related to either the internal or external environment i.e., competitors, customers, employees, etc. Additionally, the study measured the breadth of managerial attention by classifying sentences when they mentioned specific geographic regions. This study found that top management teams that focused on the external environment and attended to diverse elements in the environment were more likely to pursue expansive strategic postures measured by foreign sales, foreign production and geographic dispersion of subsidiaries. Thus the inernal vs external focus of managerial attention was linked to the strategic posture of the firm.

Yadav et al (2007) examined senior manager attention to the internal and external environment and the effect on technical innovation. Set in the banking industry during the introduction of internet banking, technical innovation was measured by the speed of detection (registering a domain name), the speed of development (the date online transaction capability went live) and the breadth of deployment (the number of features rolled out). Using the shareholders letter in the annual report word counts were used to operationalize external and internal attention. Senior manager attention to the future as well as the internal and external environment influenced the speed of detection and speed of development of internet banking. Senior manager attention to the future was also influential on the breadth of deployment of internet banking.

Nadkarni and Barr (2007) did not operationalize internal vs external attention. Instead, they examined the impact of attention focus to the task sector and to the general sector of the environment. Attention to the task sector is analogous to attention to the internal environment while attention to the general sector is analogous to attention to the external environment. Nadkarni and Barr's (2007) research examines the effect of managerial attention on the speed of strategic actions measured as the number of days between an environmental event and the organization's response. Attention focus was measured using management's annual letter to shareholders to create causal maps of managerial cognition. Measures of centrality were applied to the task and general sectors of the maps and used to estimate managerial attention focus. Nadkarni and Barr (2007) found that increased managerial attention to the task sector speeded strategic actions in response to changes in the task sector. Tests of mediation found that managerial attention mediated the relationship between the high velocity environment and the speed of strategic actions. Thus, the focus of managerial attention was linked to the speed of strategic actions.

D'Aveni and MacMillan (1990), Levy (2005), Yadav et al (2007) and Nadkarni and Barr (2007) all examined the impact of management's focus of attention on outcome variables including innovation. In all these studies, the focus of managerial attention demonstrated a significant relationship with firm outcomes. Managerial attention impacted firm survival, cognitive bias, strategic posture, the speed of strategic action and firm level innovation. However, results for the impact of these attention focuses were mixed. D'Aveni and MacMillan (1990) found failing firms paying more attention to the internal environment while Nadkarni and Barr (2007) found such a focus on the task sector important to quicker strategic actions. Levy (2005) found that an external focus was positively related to an expansive strategic posture. Yadav et al (2007) found that senior manager attention to the internal and external environment influenced the speed of detection and speed of development of internet banking. However, it was senior manager attention to the future that influenced the breadth of deployment.

Cho and Hambrick (2006) did not divide managerial attention into internal and external focuses. Instead, they examined the level of entrepreneurial attention and its impact on entrepreneurial strategy. Specifically, they studied the level of entrepreneurial attention, based upon the work of Mintzberg (1973), as a moderating variable between TMT demographics, incentive structures and entrepreneurial strategy. Entrepreneurial attention was measured based upon the annual letter to shareholders. Entrepreneurial strategy was measured using objective indicators of each airline's realized strategy, measured as the number of city-pairs served, the number of planes, the level of passenger service expenditures and advertising and sales expenditures. Cho and Hambrick (2006) found a significant relationship between entrepreneurial attention and entrepreneurial strategy. Cho and Hambrick's (2006) methodology expanded the capability of attention research. Kaplan (2008) and Eggers and Kaplan (2008) examined the effect of senior manager attention to innovation and further developed attention research methodology similar to Cho and Hambrick (2006).

Eggers and Kaplan (2008) explored the role of managerial cognition in the timing of an incumbent's adoption of a radical new technological innovation. Set in the telecommunications industry during the fiber-optic revolution, the study examines 26 telecommunications firms over a 25 year period. Grounded measures were created for senior manager attention based upon a review of the totality of words in the shareholders letters across the sample. A word count analysis was used to operationalize senior manager attention to emerging technologies, existing communication technologies and the industry in general. Innovation adoption is measured based upon the timing of the firm's entry into the optical product market. The study finds that senior manager attention to an emerging technology is positively associated with subsequent product market innovation. Further, when the senior management places more attention on existing technologies, subsequent product market innovation is delayed. Examining the interaction between senior manager attention and firm capabilities, Eggers and Kaplan find that senior manager 'attention appears most relevant to understanding firm behavior in situations where basic organizational components in the emerging technology are lacking' (2008, p23). Thus senior manager attention to an emerging technology facilitates product market innovation.

Kaplan (2008) asks two research questions: First, what is the interaction of senior manager attention and a firm's customer orientation on technical innovation during a technological revolution? Second, what is the interaction of senior manager attention and a firm's capabilities on technical innovation during a technological revolution? The study uses a sample of 71 communications technology suppliers and extends from 1982 -2001, through the revolutionary introduction of fiber optics into the industry. Innovation is operationalized by a firm's investment in optical technologies as measured through its optical patenting emphasis. Senior manager attention is operationalized as attention to optics and is measured by a count of all words in the annual shareholders letter related to optics. Kaplan (2008) finds that senior manager attention to optics has an important main effect on innovation measured by changes in a firm's optical patenting rates. Further, this effect is intensified if firms do not have prior related competencies in the optical arena or do not have a customer orientation that favors investment in the optical technology. Similar to other studies, Kaplan (2008) finds an affect of senior manager attention on firm innovation. However, similar to Eggers and Kaplan (2008), Kaplan (2008) finds that the effect of senior manager attention interacts with organizational variables, specifically customer orientation and a firm's existing capabilities.

Yadav et al(2007), Kaplan (2008) and Eggers and Kaplan (2008) have implications for the methodology applied in attention research. Yadav et al (2007) introduces future orientation as a new dimension that can be used to examine senior manager attention. Kaplan (2008) and Eggers and Kaplan (2008) utilize a new grounded methodology to operationalize senior manager attention. Kaplan (2008), Eggers and Kaplan (2008) and Cho and Hambrick (2006) all use word counts to operationalize attention. Cho and Hambrick (2006) start with Mintzberg (1973) as a theoretical basis of how managerial attention might be concentrated. From this base, they develop a dictionary of entrepreneurial words and then examine shareholders letters to determine the level of entrepreneurial attention. Eggers and Kaplan (2008) and Kaplan (2008) approach senior manager attention measurement from a grounded perspective. They start with a list of all the words used in the annual reports, of the sample companies, and identify those words associated with constructs of interest. Senior manager attention to the construct is then based upon the concentration of the identified words. This methodology holds promise for a greater dimensionalization of managerial attention. However, by generating study specific measures, these studies do not contribute to the larger development of an understanding of a typology of managerial attention.

Summary and Synthesis of Attention Impact, Dependent Constructs

The prior subsection reviewed the effects of managerial attention as studied within strategic management research. There is general theoretical and empirical agreement demonstrating a main effect of managerial attention on both firm actions and strategic outcomes, including firm level innovation. Findings related managerial attention to formalized organizational action (March et al., 2000), firm survival (D'Aveni & MacMillan, 1990), strategic posture (Levy, 2005), the speed of strategic action (Nadkarni & Barr, 2007), entrepreneurial strategy (Cho & Hambrick, 2006) and firm level innovation (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007). Such findings are in line with the Child's (1972) view of strategic choice.

Yadav et al (2007), Kaplan (2008) and Eggers and Kaplan (2008) identify a main effect for senior manager attention on firm innovation. Kaplan (2008) also points out that the influence of senior manager attention interacts with organizational variables. Senior manager attention had greater influence on innovation outcomes when a firm possessed less of a specific capability. This interaction is interesting in light of Ocasio's (1997) argument that a firm's resources are important influences on managerial attention. Given the importance of a firm's resources on innovation outcomes (Fleming, 2001) the lack of a more thorough treatment of the role of senior manager attention and resource structure is a significant gap in the attention and innovation literatures. This subsection reviewed the strategy literature that has examined the effect of managerial attention on firm outcomes, specifically firm level innovation. The following brings together the conclusion from the review of attention antecedents and consequences.

2.4.6 Managerial Attention Summary

This section summarizes and synthesizes the gaps and research questions identified through this literature review of managerial attention antecedents and consequences. Managerial attention is of fundamental importance to a belief of managerial agency (Child, 1972). Ocasio (1997) has argued that the generating and focusing of managerial attention is a central role of the firm. However, considering the conceptual importance of the topic and the body of research reviewed, strategy research has thinly treated how managerial attention differs between firms, how it is shaped and concentrated and what actions and outcomes result from differences in managerial attention. This gap has not gone unnoticed. Hutzschenreuter and Kleindienst (2006) in a recent review of the strategy process literature pointed out:

> '…current research falls short in addressing the question of how decision makers decide on what to decide and how decision makers' attention is channeled and distributed within an organization…we strongly believe that strategy-process research would greatly benefit from exploring this question…Why do firms attend to some issues but not others? Why do issues get attention in some firms but not in others?...What are the forces that shape a firm's strategic agenda?' (2006, p708).

Managerial attention is important to both firm actions and outcomes (Cho & Hambrick, 2006; D'Aveni & MacMillan, 1990; Howard-Grenville, 2006; Levy, 2005; March et al., 2000; Nadkarni & Barr, 2007), including firm level innovation (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007).

Managerial Attention is influenced by cognitive, environmental, and organizational variables. The cognitive dispositions of the dominate coalition matter (e.g. Hambrick, 2007; Hambrick & Mason, 1984) but have been criticized for being invariant measures in the face of shifting environmental conditions. Managerial Attention has significant theoretical importance as the first step in the cognitive processing model and has been shown to be a separate construct from cognitive dispositions with independent effects on technology adoption (Kaplan, 2008). Environments used to study managerial attention are traditionally undergoing some form of external shock (e.g. Cho & Hambrick, 2006; Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007) or have characteristics indicating a high degree of managerial discretion (e.g. Abrahamson & Hambrick, 1997; Cho & Hambrick, 2006; Nadkarni & Narayanan, 2007). Managerial attention is also influenced by the presence/intensity of organizational variables (Kaplan, 2008) institutional embeddedness (Hung, 2005) and by changes in organizational variables (Cho & Hambrick, 2006). Prominent in these studies is an examination of the effect of managerial attention that is focused on the internal (task) and the external (general) environments. This is a limited dimensionalization of managerial attention and results of these studies are inconsistent (D'Aveni & MacMillan, 1990; Nadkarni & Barr, 2007). Recent techniques have explored alternative methodologies to measure and dimensionalize managerial attention (Cho & Hambrick, 2006; Eggers & Kaplan, 2008; Kaplan, 2008; Nadkarni & Narayanan, 2007; Yadav et al., 2007).

Ocasio's (1997) attention based view of the firm focused on the firm's internal rules, social relationships and resources in structuring managerial attention. Of these three categories, the influence of a firm's resources on managerial attention remains unaddressed and undeveloped. The role of the firm's unique heterogeneous resources in affecting managerial attention remains unexplored. This gap in the research on managerial attention is surprising given the focus in the strategy literature on the importance of a firm's unique resources (Barney, 1991; Barney et al., 2001) and importance attributed to both resource structure (Fleming, 2001) and cognition on firm innovation (e.g. Bantel & Jackson, 1989; Barringer & Bluedorn, 1999; Damanpour & Schneider, 2006; Kaplan et al., 2003; Yadav et al., 2007).

Except for environmental change, attention research has largely dealt with the antecedents of attention and the effects of attention separately (Table 4). See Cho and Hambrick (2006) for an exception. As noted above, the attention literature has partially and independently examined elements of three antecedent areas to managerial attention; the external environment, the internal environment and the cognitive predisposition of the dominate coalition. No research was identified in the literature review, which developed an integrative model of managerial attention addressing the relationship of all three elements or their relative merit in different contexts. While an integrative model is desirable, it would require greater understanding of the influences of each antecedent area. However, the lack of attention to the role a firm's heterogeneous resources have on managerial attention is most significant due to the prominent role a firm's resources have had on strategic management theories (Barney, 1991; Barney et al., 2001). Prior to being able to develop any integrative model of managerial attention, this gap must be addressed. The lack of research regarding the influence of a firm's heterogeneous resources on managerial attention leads to the following research questions: What is the influence of a firm's core technical knowledge structure on managerial attention? And, What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes?

Exploring these research questions will address in part Hutzschenreuter and Kleindienst (2006) call for greater understanding of the forces that shape a firm's strategic agenda by increasing our understanding of managerial attention. In order to more fully understand the importance of heterogeneous resources, the following section very briefly reviews this literature and identifies core technical knowledge concentration and ease of recombination as important influences on innovation for high technology firms.

2.5 Core Resource Structure and Innovation

The enabling role resources play on innovation can be found in the writings of the some of the fields seminal thinkers, including Schumpeter (1942), Penrose (1959) and Nelson and Winter (1982). Schumpeter (1942) was primarily concerned with the influence of environmental change on organizations. A central idea in his thinking was that resources facilitate the ability for organizations to change. Resource rich organizations had a higher probability of surviving environmental change due to a greater capacity for innovative and imitative change. From Schumpeter's (1942) perspective resources facilitate organizational adoption of process and technology innovations that allow a firm to adapt to changing environments. Nelson and Winter (1982) extended Schumpeter's (1942) idea. In their perspective, a firm's ability to react to environmental change is influenced by the firm's path dependent collection of resources and routines. A firm with a larger portfolio of path dependent resources and routines has a greater variety of possible actions available to it. Faced with environmental change the larger choice set allows the firm to respond more innovatively. Both Schumpeter (1942) and Nelson and Winter (1982) view the firm's portfolio of path dependent resources as key to firm level adoption of technical and process innovations.

Penrose (1959) also saw an important relationship between a firm's resources and innovation. However, for her, resources (e.g., knowledge, managerial talent, physical assets, reputation) are more active in directing innovation. In Penrose's (1959) view, firms necessarily develop stocks of underused or unused resources. It is these underutilized resources that are the primary impetus and provide the direction of innovation. Following this logic, firms with a greater stock of under or un-utilized resources are in a better position to innovate and grow.

For Schumpeter (1942), Nelson and Winter (1982) and Penrose (1959) a firm's resources can facilitate or implicitly direct firm level innovation. These linkages were due to the way resources facilitate, direct and provide opportunity and options for technical and administrative innovation. From Schumpeter (1942) and Nelson and Winter's (1982) perspectives, little role is given to strategic managers. From Penrose's (1959) perspective, strategic managers are critical links in the relationship between a firm's resources and innovation.

Implied in the writings of Schumpeter (1942), Penrose (1959) and Nelson and Winter (1982) is the important concept that some resources are more important than other resources. Organizational scholars generally agree that there are resources which are more central or core to an organization's activities and others which are more peripheral (e.g. Hannan & Freeman, 1984; Leonard-Barton, 1992; Lyles & Schwenk, 1992; Prahalad & Hamel, 1990; Siggelkow, 2002; Snow & Hrebiniak, 1980). Every firm resource is not strategically relevant (Barney, 1991). Similar ideas are reflected in the capabilities literature. Amit and Schoemaker (1993, p 35) refer to capabilities as a firm's capacity to deploy resources to affect a desired end. Snow and Hrebiniak (1980) used the term 'distinctive competence' while Prahalad and Hamel (1990) used the term 'core competence' to reflect ideas that certain firm capabilities are more important than others. This is reflected in the definition of core capabilities used by Leonard Barton who writes of core capabilities as, 'a set of differentiated skills, complementary assets and routines that provide the basis for a firm's competitive capacities...' (1992, p 112).

Identification of a universal set of core resources or capabilities is elusive. However, Siggelkow (2002) points out a general agreement among organizational scholars on the underlying properties of a core resource. A resource is considered core if it has either a high interdependency with other organizational components or a large influence on future organizational components. Interdependency means that a core resource is highly connected with other components of an organization such that a change in the core resource would impose changes on the related organizational components (Hannan, Burton, & Baron, 1996; Siggelkow, 2002). Changes in non-core resources would impose minor if any changes on other components within the organization. Resources or capabilities with high influence, significantly affect the development and direction of future organizational components (Siggelkow, 2002).

For science intensive high technology industries focused on innovation, such as the biotechnology industry, technical knowledge is a critical core resource (e.g DeCarolis & Deeds, 1999; Gittelman & Kogut, 2003; Hall & Bagchi-Sen, 2002; Phene, Fladmoe-Lindquist, & Marsh, 2006; Shan & Song, 1997). In line with Siggelkow (2002), I define core technical knowledge as a firm's explicit technical knowledge that has the potential for or currently creates a high interdependency with other organizational components or a large influence on future organizational components. As will be further explained in the methods section, the patents held by science intensive high technology industries will be used to measure a firm's core technical knowledge. A change in the knowledge underlying a firm's patents would require changes in multiple components and processes throughout the firm. The knowledge embedded in a firm's patents also has significant impacts on future organizational components.

Concentration and Ease of Recombination are concepts used to understand the structure and impact of a firm's core technical knowledge (e.g. Cohen & Levinthal, 1990; Fleming & Sorenson, 2001; Henderson & Cockburn, 1994; Huber, 1991; Katila & Ahuja, 2002; Teece, Rumelt, Dosi, & Winter, 1994; Wu & Shanley, 2008). Concentration in a firm's core technical knowledge refers to the depth of a firm's knowledge across the categories of knowledge the firm has experience with (e.g. Cohen & Levinthal, 1990; Fleming & Sorenson, 2001; Henderson & Cockburn, 1994; Huber, 1991; Katila & Ahuja, 2002; McGrath & Nerkar, 2004; Teece et al., 1994; Wu & Shanley, 2008). A high concentration in a firm's core technical knowledge portfolio means that the firm has focused its knowledge acquisition around a few core categories. High concentration represents a clear distinction between a firm's core and peripheral knowledge (Lyles & Schwenk, 1992; Prahalad & Hamel, 1990). Ease of Recombination is a portfolio level measure of the degree to which a firm's knowledge areas easily combine with other knowledge areas (Fleming & Sorenson, 2001; Fleming & Sorenson, 2004).

Concentration and Ease of Recombination have been used to understand the influence of a firm's core technical knowledge structure on firm innovation through the concepts of organizational learning (e.g. Cohen & Levinthal, 1990) and recombinant innovation (e.g. Fleming, 2001). Organizational learning links concentration in firm's technical expertise to innovation through the concept of absorptive capacity (e.g. Cockburn & Henderson, 1998; Cohen & Levinthal, 1990; Huber, 1991; van Wijk, Jansen, & Lyles, 2008; Zahra & George, 2002). In a meta analysis of 14 years of research on organizational learning, van Wijk, Jansen and

Lyles (2008) found strong associations between absorptive capacity and organizational knowledge transfer and innovativeness. High concentration representing deep knowledge has been found to enhance a firm's ability to absorb related information (e.g. Cohen & Levinthal, 1990; Henderson & Cockburn, 1994; Wu & Shanley, 2008). By concentrating in areas where it has already developed prior knowledge a firm has a higher likelihood of innovative success (Cohen & Levinthal, 1990). Henderson and Cockburn (Henderson & Cockburn) focused on the importance of deep knowledge to innovation within pharmaceutical firms. Wu and Shanley (2008) used the electro-medical device industry and measured the concentration of a firm's knowledge using the USPTO patent classification system. Concentration in a firm's patent portfolio significantly influenced the firm's innovation outcomes, measured as new patent applications (Wu & Shanley, 2008). However, too much concentration is more likely to lead to innovations that are incremental extensions of the firm's historic technological domain (Katila & Ahuja, 2002; March, 1991) and less innovative (Sorensen & Stuart, 2000). Concentrating on familiar technologies can preclude the identification of useful technologies that may be technologically distant (Fleming & Sorenson, 2001). The technological focus that Comallows a firm to develop a distinctive competence may lead to a 'core rigidity' (Leonard-Barton, 1992), a 'competency trap' (Levitt & March, 1988), a 'familiarity trap', a 'maturity trap' or a 'propinquity trap' (Ahuja & Lampert, 2001). Low concentration, indicating a broad experience base can translate into a wider set of categories senior managers use to understand the firm and its environment (Daft & Weick, 1984; Prahalad & Bettis, 1986; Starbuck & Milliken, 1988). Henderson and

Cockburn (1996) find that low concentration in research efforts are more productive due to potential economies of scope.

In addition to the absorptive capacity literature, the recombinant innovation literature links concentration as well as Ease of recombination to firm innovation. A portfolio with a high Ease of Recombination is relatively easily combined with other knowledge areas, thus influencing the ease of innovation possibilities. The difficulty of knowledge combination arises from the degree of correlation between the knowledge being combined. Knowledge areas with no correlation are easy to combine as each knowledge area when in combination continues to act independently. Knowledge areas that are highly correlated act in unpredictable ways when combined and are difficult to combine effectively (Fleming, 2001).

In summary, the RBV is a fundamental theoretical perspective within strategy research. Within this literature, a firm's core assets are critical to firm performance. For science intensive high technology firms, core technical knowledge is a critical core resource. A firm's core technical knowledge is made up of component knowledge elements in a portfolio relationship. The structural properties of these relationships are theoretically important to firm performance and innovation outcomes. Measures of knowledge concentration and ease of recombination have been linked to firm innovation and firm performance however, there is a general call for a better understanding of the effect of these relationships on the firm and its capabilities (van Wijk et al., 2008). Ease of Recombination has not been addressed at the firm level but has shown significant impact on innovation outcomes at the innovation level (2001; 2004). This lack of thorough treatment of the structural properties of the core resource portfolio is a gap in the resource based and innovation literatures.

2.6 Summary of Gaps and Research Questions

Innovation is a central concept to theories of economic growth (Schumpeter, 1934). This review examined two literatures which are independently influential on firm level innovation; managerial cognition (e.g. Barringer & Bluedorn, 1999; Damanpour & Schneider, 2006; Yadav et al., 2007) with a focus on managerial attention (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007) and core resource structure (e.g. Cohen & Levinthal, 1990; Fleming & Sorenson, 2001; Henderson & Cockburn, 1994 ; Wu & Shanley, 2008). The influence on innovation outcomes of these two literatures operate through the effects of exploratory and local search (e.g. Cyert & March, 1963; Dosi, 1988; Fleming & Sorenson, 2004; March & Simon, 1958a; Stuart & Podolny, 1996; Teece, 1988). The link between core resource structure and exploitive innovation outcomes is often studied and operates through local search (e.g. Dosi, 1988; Stuart & Podolny, 1996). The link between senior management attention and exploratory innovation outcomes is theoretically clear (e.g. Child, 1972; Greve, 1998; Lant et al., 1992) but largely unexamined.

The dominant process model of managerial cognition emphasizes the importance of managerial attention (Cowan, 1986; Daft & Weick, 1984; Dutton et al., 1983; Dutton & Jackson, 1987; Hambrick & Mason, 1984; Kiesler & Sproull, 1982; Lyles & Mitroff, 1980). Even with such a strong theoretical footing, relatively little research has addressed the role of managerial attention on firm level exploratory innovation. The few studies that have addressed the influence of senior management attention on technical adoption have found main as well as moderating effects (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007). While this is a start, research gaps remain. Ocasio (1997) argues that the generating and focusing of managerial attention is a central role of the firm. Of the organizational antecedents identified by Ocasio (1997) the influence of a firm's heterogeneous core resources on managerial attention remains unexamined. The influence of core technical knowledge structure on managerial attention is unexamined and the role of managerial attention on a firm's exploratory innovative outcomes is unexamined. These gaps lead to these research questions: What is the influence of a firm's core technical knowledge structure on managerial attention? What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes? The following chapters develop a theoretical and methodological approach to answer these questions.

3. HYPOTHESIS DEVELOPMENT

3.1 Overview of the Research Model

The resource and knowledge based literatures emphasize the importance of a firm's core resources to firm performance (Barney, 1991; Grant, 1996; Wernerfelt, 1984). For dynamic and technologically intensive industries, core technical knowledge resources have a demonstrated direct effect on innovation outcomes (e.g. Fleming & Sorenson, 2001; George et al., 2007; Hall et al., 2001; Henderson &

Cockburn, 1994; Henderson & Cockburn, 1996; Lin et al., 2006; Patel & Pavitt, 1997; Trajtenberg et al., 1997). Other scholars emphasize the importance of managerial cognition in the innovation process, especially with respect to exploratory search (e.g. Bantel & Jackson, 1989; Barker & Mueller, 2002; Carpenter et al., 2004; Damanpour & Schneider, 2006; Deeds et al., 2000; DeTienne & Koberg, 2002). Recently, scholars have pointed toward the importance of managerial attention on a firm's innovative outcomes (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007). However, attention as the first step in the cognitive processing model remains an understudied aspect of managerial cognition and firm innovation.

The model integrates the resource based and attention literatures to propose that managerial attention mediates the core technical knowledge structure – exploratory innovation relationship and further, that those structural elements are influential on managerial attention.

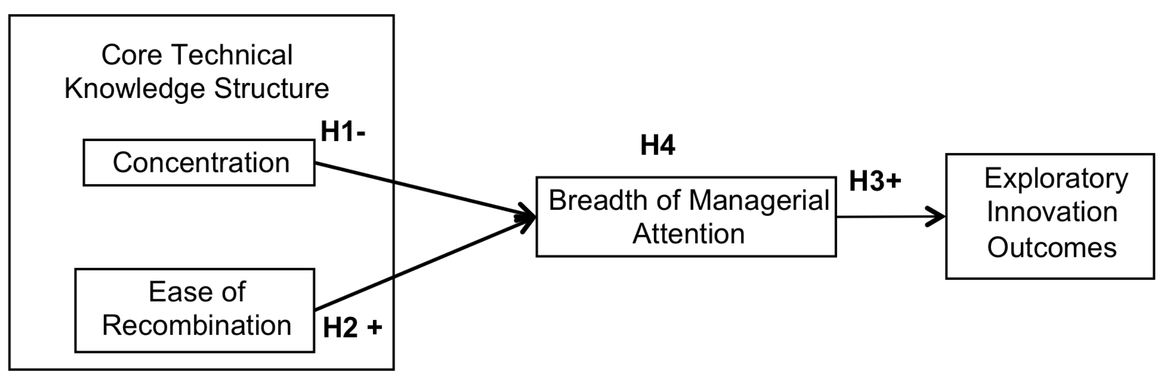


Figure 1

Theoretical Model

3.2 Core Resources and Managerial Attention

The RBV is a central frame within strategy literature. However, the RBV has been criticized for lack of attention to managerial actions responsible for the creation of resource combinations (Priem & Butler, 2001). Sirmon, Hitt and Ireland (2007, p 274) write 'the processes by which firms obtain or develop, combine, and leverage resources to create and maintain competitive advantages are not well understood.' Scholars have begun to address the importance of managerial action within the RBV frame as evidenced in the work of Makadok (2001) and Sirmon et al (2007, p 274).

Makadok (2001) argues that there are two fundamental managerial roles in rent creation: resource picking and capability building. In the resource picking mechanism, senior managers attempt to acquire resources for a cost below the value supplied to the firm. Denrell, Fang and Winter (2003) have argued that factor market prices on new resources and resources going to be used in new ways are often based on incomplete information. This argues strongly for an emphasis on managerial perceptions in the acquisition of factor market resources. Superior information originates in management's understanding of the firm's existing resources and capabilities and how the value of the resource being acquired enhances or is enhanced by its relationship to the firm's existing resources and capabilities (Barney, 1986; Makadok, 2001). In this way, the firm's resource picking success is dependent upon senior management's understanding of the firm's existing resources and capabilities and how the new resource will interact with the existing portfolio of resources and capabilities.

In the capability building mechanism, senior management's role is architectural (Makadok, 2001). In contrast to resources acquired in the factor market, capabilities are organizationally embedded and cannot be easily bought; therefore they must be built (Teece et al., 1997). Architecting new capabilities requires an intimate understanding of a firm's existing resources and their interactions. While Makadok (2001) addresses managerial action from a broad perspective, Sirmon et al (2007) more directly addresses resource management interactions that the top management team engages in to create competitive advantage. These actions include resource structuring (acquisition, accumulation and divestiture), capability bundling (combinations) and capability leveraging (application within the environment to create value).

Underlying Makadok (2001) and Sirmon et al's (2007) work is a cognitive perspective. Makadok's (2001) resource picking mechanism is reliant upon the senior management's understanding of the firm's existing resources and capabilities and how the value of the resource being acquired enhances or is enhanced by its relationship to the existing resources and capabilities. Makadok's (2001) capability building mechanism is architectural in nature and requires an intimate understanding of a firm's existing capabilities and resources. In Sirmon's (2007) work, a cognitive perspective is more pronounced. Feedback and decision making are central to Sirmon's model; involvement by senior management in all "the different stages of resource management is necessary, because feedback from the market regarding customer needs influences the sub-processes employed in each component" (2007, p 287).

In both Makadok (2001) and Sirmon's (2007) work, it is assumed that existing resources and capabilities influence managerial decision-making. However, as noted previously, a gap in the literature exists. The link between existing core resources, their structure and managerial cognition is not developed. We do not understand how or in what way the structure of a firm's core resources influences managerial attention and therefore decision-making.

Core Resource Structure and Managerial Attention

Both of the literatures related to strategic choice (Child, 1997) and the upper echelon view (Hambrick & Mason, 1984) emphasize that the cognition of the top managers matter to firm actions. Humans possess limited information processing capacity (Simon, 1947; Sproull, 1984) and operate in an information environment that is munificent, complex and ambiguous (Schwenk, 1984; Starbuck & Milliken, 1988). Schemas are the mental filters through which top managers recognize issues, interpret them and eventually take action (e.g. Daft & Weick, 1984; Hambrick, 1982; Huff, 1982; Prahalad & Bettis, 1986; Starbuck & Milliken, 1988). The role schemas play, in cognition is profound (e.g. Daft & Weick, 1984; Huff, 1982; Lyles & Schwenk, 1992; Nadkarni & Barr, 2007; Prahalad & Bettis, 1986; Thomas, Clark, & Gioia, 1993). Schemas improve cognitive economy by organizing the information environment (Walsh, 1995). They facilitate information recognition and processing and provide a basis for information evaluation thus influencing decision-making (Walsh, 1995).

Similar to the way core resources and capabilities are developed over time in a path dependent process (Dierickx & Cool, 1989; Helfat & Peteraf, 2003; Makadok, 2001; Teece et al., 1997), schemas are developed over time based upon learning processes grounded in experience, experimentation and feedback (Brewer & Treyens, 1981; Lyles & Schwenk, 1992; Prahalad & Bettis, 1986; Rumelhart, 1980). Makadok (2001, p 389) notes that effective resource picking is dependent upon management's 'expectations about value' which are cognitive characteristics formed over time. The management team accumulates experience as it attempts to operate a capability. The feedback of these attempts creates 'improvement over time in carrying out the activity as a team' (Helfat & Peteraf, 2003, p1002). This process can be iterative where 'trials of techniques alternate with additional search for alternatives, as the team reflects on what it has learned from the trials' (Helfat & Peteraf, 2003, p 1002). Dierickx and Cool (1989) emphasize the importance of management engaging over time in an ongoing and consistent way in order for the firm to accumulate strategic asset stocks. Teece, Pisano and Shuen (1997) note that dynamic capabilities are the result of managerial and organizational processes shaped by the firm's position and its evolutionary path. As top management engages with and develops a core resource portfolio (Helfat & Peteraf, 2003; Makadok, 2001; Sirmon et al., 2007), they are inherently developing an understanding of the portfolio's capabilities that is being shaped by the portfolio's characteristics (Brewer & Treyens, 1981; Lyles & Schwenk, 1992; Prahalad & Bettis, 1986; Rumelhart, 1980).

The organizational learning literature points toward a relationship between structure in a firm's core technical knowledge and managerial attention through the concept of absorptive capacity. Cohen and Levinthal (1990, p 128) define absorptive capacity as a firm's ability to 'recognize the value of new information, assimilate it and apply it to commercial ends.' Prior knowledge is central to a firm's 'absorptive capacity' as it is the foundation of the firm's ability to evaluate and utilize outside knowledge (Cohen & Levinthal, 1990). Zahra and George (2002) in a review and re-conceptualization of Cohen and Levinthal's (1990) original concept, identify four dimensions of absorptive capacity; Acquisition, Assimilation, Transformation and Exploitation. Acquisition and Assimilation are dimensions of Potential Absorptive Capacity and precede Transformation and Exploitation, which are dimensions of Realized Absorptive Capacity. I focus here on Potential Absorptive Capacity, which makes the firm receptive to acquiring and assimilating external knowledge (Zahra & George, 2002).

The Acquisition stage is defined as 'a firm's capability to identify and acquire externally generated knowledge' while the Assimilation stage refers to a firm's ability to interpret and understand the information obtained from those external sources (Zahra & George, 2002, p 189). Zahra and George (2002) emphasize that it is a firm's prior knowledge that forms the basis of Potential Absorptive Capacity. Prior knowledge sets the initial point for organizational search (e.g. Christensen & Bower, 1996; Cyert & March, 1963), including technological search (Rosenkopf & Nerkar, 2001) and also affects the perceptual schemas that influence knowledge interpretation. Through its effect on search and perceptual schemas the structure of a firm's core technical knowledge influences the breadth of managerial attention.

Research on innovation has a substantial history of exploring the effect of search on innovation outcomes (e.g. Dosi, 1988; Fleming & Sorenson, 2004; Stuart & Podolny, 1996; Teece, 1988). Local search is closely related to a firm's current technical knowledge base (Stuart & Podolny, 1996) and constrains the direction of innovation to areas that are near the firm's current technological base (e.g. Dosi, 1988; Stuart & Podolny, 1996). By concentrating knowledge generation in areas where it has already developed prior knowledge a firm has a higher likelihood of innovative success (Cohen & Levinthal, 1990). However, those innovations are more likely to be incremental extensions of the firm's historic technological domain (Katila & Ahuja, 2002; March, 1991) and less innovative (Sorensen & Stuart, 2000). Concentrating on familiar technologies can preclude the identification of useful technologies that may be technologically distant (Fleming & Sorenson, 2001). The technological focus that allows a firm to develop a distinctive competence may lead to a 'core rigidity' (Leonard-Barton, 1992), a 'competency trap' (Levitt & March, 1988), a 'familiarity trap', a 'maturity trap' or a 'propinquity trap' (Ahuja & Lampert, 2001). Although local search can be incrementally detrimental to exploratory innovation, firms often continue to engage in local search until some aspiration level failure triggers exploratory search (Ahuja & Katila, 2004; Baum & Dahlin, 2007; Chen & Miller, 2007; Greve, 1998; Lant et al., 1992). Without such a triggering event, it is the structure of a firm's underlying core knowledge that establishes the initial point of local search and therefore influences the breadth of managerial attention.

Firm's with higher concentrations in their core knowledge portfolios will have fewer search spaces to initiate from and a lower breadth of attention than firms with lower concentrations and therefore more search spaces to engage initiate from. Zahara and George (2002), in their development of Potential Absorptive Capacity, point out that prior knowledge affects not only the initial search space but also the perceptual schemas that influences knowledge acquisition.

A core technical knowledge portfolio with a low concentration indicates a wide knowledge base. Such a knowledge base influences absorptive capacity as it 'increases the prospect that incoming information will relate to what is already known' (Cohen & Levinthal, 1990, p.131). The recognition process implied by Cohen and Levinthal (1990) is cognitive and dependent upon the incoming information being relevant to management's schema which has been influence by management's engagement with the firm's core technical knowledge (e.g. Daft & Weick, 1984; Hambrick, 1982; Huff, 1982; Prahalad & Bettis, 1986; Starbuck & Milliken, 1988). Senior managers engaged with a core technical knowledge portfolio of lower concentration will have a wider net with which to identify, attend and interpret information potentially relevant to the firm (Daft & Weick, 1984; Prahalad & Bettis, 1986; Starbuck & Milliken, 1988).

A firm's core technical knowledge resources can also be more highly concentrated. A high concentration means that the firm has focused its knowledge acquisition around a few core categories, representing a clear distinction between a firm's core and peripheral knowledge (Lyles & Schwenk, 1992). Prahalad and Hamel

(1990) suggest that it is important for a firm to develop concentrated experience in order to develop a core competence. However, development of a core technical knowledge portfolio of greater concentration means that management will engage with more highly related and non-diverse components. The more management engages with a core knowledge portfolio of greater depth, the more developed will be management's understanding of the portfolio's capabilities within a narrower area. A deep understanding of a concept area can also be referred to as a core concept. New information is recognized, interpreted and evaluated in relationship to the core concepts embedded in schemas (Kiesler & Sproull, 1982; Walsh, 1995). New information is automatically interpreted in relationship to a core concept and will seem more relevant if it can be fit into an existing core concept than if it does not (Kiesler & Sproull, 1982). Core concepts, once established are difficult to change (Carley & Palmquist, 1992) and have been linked to strategic persistence (Nadkarni & Narayanan, 2007) as well as an inability to effectively innovate (Tripsas & Gavetti, 2000). Managers who have engaged with a core technical knowledge portfolio of greater depth will have fewer but stronger core concepts available for recognizing, interpreting and evaluating information.

This section has argued that the structure of a firm's core technical knowledge will impact the breadth of managerial attention through its effect on the initial space that search will begin from and through its influence on the cognitive schemas of the senior managers as they impact the recognition and interpretation of external information. To make these argument somewhat less abstract, I would like to draw an analogy to a common saying paraphrased as "To a surgeon, every symptom indicates surgery." This saying points out the influence of core skills and beliefs on incoming information. Our surgeon, with a concentrated knowledge, is primed to interpret the environment by the way it relates to their underlying core resource, surgery skills. To continue the medical analogy, contrast the surgeon's perspective with that of a family practitioner, Doctor of Osteopathy. The D.O., with a broader knowledge base, is more likely to have a wider perspective and recognize more opportunities to address the disease process than the surgeon. The wider knowledge base both allows the D.O to recognize more alternatives and have more investigative paths to focus on. Based upon these arguments, I hypothesize:

H1: Concentration in a firm's Core Technical Knowledge Portfolio is negatively related to the Breadth of Managerial Attention.

Knowledge recombination is central to the innovation process (Hargadon & Sutton, 1997; Henderson & Clark, 1990; Schumpeter, 1939). For firms in technologically intense industries recombination is critical to innovation. However, not all knowledge areas can be combined with the same level of simplicity. Ease of Recombination is the degree to which a knowledge area easily combines with other knowledge areas. The sensitivity of a knowledge area to changes in other areas of knowledge it is dependent upon drives the Ease of Recombination. Paraphrasing the example used by Flemming (2001), the performance of a semiconductor is highly dependent upon the level of impurity added to the crystal semiconductor lattice, called a dopant. Changes in the level of the dopant are measured at the atomic level. A change by 1 part in 10^8 can alter the resistance of the semiconductor by a factor of

24,100 (Millman, 1979) effecting the ultimate performance of the chip. The difficulty of combining and reliably manufacturing silicon semiconductors is a function of the interdependence of these two component knowledges.

A portfolio with a high Ease of Recombination is made up of knowledge areas are more easily recombined with other knowledge areas. This means that the individual knowledge areas that make up the portfolio largely act independently when combined into an innovation and thus are more easily combined in the creation process. In opposition to this, a portfolio with a low Ease of Recombination is made up of knowledge areas that are not very easily recombined with other knowledge areas. This means that the individual knowledge areas that make up the portfolio are highly reliant on other knowledge areas and interact in combination in unpredictable ways. Due to the cognitive limits of individuals (March & Simon, 1958a) and the complexity of these interactions, innovative possibilities are more difficult to understand and develop (Fleming & Sorenson, 2001; Fleming & Sorenson, 2004). Greater time and effort is needed to understand the relationships, interactions and possibilities the portfolio holds (Fleming & Sorenson, 2001). Understanding the core capabilities of the firm is a key role of senior management and critical to identifying environmental opportunity the firm can take advantage of (e.g. Prahalad & Hamel, 1990; Stalk, Evans, & Shulman, 1992). In order for senior management to understand the firm's capabilities and to fulfill their role as important decision makers (Chen & Miller, 2007; Child, 1972; Ocasio, 1997), a greater portion of their attention must be turned inward (e.g. Fleming & Sorenson, 2001; Gibbons & Johnston, 1974), narrowing managerial attention and additionally leaving less time available for attending to other aspects of the firm and the environment. In addition to the internal constriction indicated, a portfolio with a low Ease of Recombination is also likely to narrow senior management attention to those aspects of the environment where the firm has already achieved some element of success. By definition, a low Ease of Recombination means that exploratory innovative activities represent higher risk ventures than proven combinations. Without the occurrence of an attention trigger (Chen & Miller, 2007; Greve, 1998; Lant et al., 1992) senior management is likely to pay attention to those combination that have proven successful in the face of unproven more difficult combinations.

As opposed to a low Ease of Recombination, a core technical knowledge portfolio with a higher Ease of Recombination represents a portfolio where the potential innovative combinations are more readily apparent, as the knowledge elements within the portfolio are more independent as opposed to interdependent. Independent knowledge elements contribute similarly in different combinations because their contribution in combination is uncorrelated. In this way, their contribution to the final innovation is more readily understandable. A portfolio with a higher Ease of Recombination means that it is easier for management to understand the possibilities of potential combinations both within the portfolio and also to knowledge in the external environment. Since the contribution of the individual elements within the firm's Core Technical Knowledge portfolio are more easily understood the cognitive demands necessary to understand the capabilities of the core technical knowledge portfolio are reduced, freeing managerial attention and allowing greater time for senior management to focus elsewhere. Further, due to the independence of the contributions, the success of potential recombinations with external knowledge is more certain. The identification of external knowledge is more likely to lead to a successful recombination reinforcing a wider breadth of managerial attention.

This section has argued that the Ease of Recombination in a firm's core technical knowledge will influence the breath of managerial attention due to senior management's need to understand the firm's capabilities and the influence the Ease of Recombination has on how easily the firm's core technical knowledge portfolio can be understood. A core technical knowledge portfolio with a high ease of recombination is easier to understand, presenting lower cognitive and time demands on senior management while also allowing for more and easier combinations with external knowledge. A core technical knowledge portfolio with a low Ease of Recombination is more difficult to understand, presenting senior management with higher cognitive and time demands as well as less obvious and higher risk combinations with external knowledge. To make this argument plainer, I return to a medical example but look at the role of a pharmacist. A primary concern of pharmacists is drug interactions. This is a concern because many drugs can interact in complex ways causing unforeseen outcomes. As a patient uses more pharmaceuticals, there is a greater potential for an adverse interaction. In such a situation, the pharmacist must pay greater attention to the possibility of drug interactions. The increase in complexity requires the pharmacist to narrow their attention and expend greater effort to address the complexity of the situation. The pharmaceuticals represent knowledge that is difficult to recombine and the need of the pharmacist to focus on drug interactions represents a narrowing of attention. Based upon these arguments, I hypothesize:

> H2: The Ease of Recombination in a firm's Core Technical Knowledge Portfolio is positively related to the Breadth of Managerial Attention.

Within the overall body of research examining technical innovation, two major factors are the influence of a firm's existing resources (e.g. Cohen & Levinthal, 1990; Fleming & Sorenson, 2001; Fleming & Sorenson, 2004; Henderson & Cockburn, 1994; Wu & Shanley, 2008) and managerial cognition (e.g. Barringer & Bluedorn, 1999; Damanpour & Schneider, 2006; Yadav et al., 2007). The preceding sections have addressed the role a firm's core technical knowledge structure has on managerial attention, arguing that portfolio Concentration and Ease of Recombination are two constructs especially influential on the Breadth of Managerial Attention. The following section examines the role managerial attention plays on a firm's exploratory innovation outcomes.

3.3 Managerial Attention and Exploratory Innovation

Managerial agency is a central concept within strategy research (Child, 1972). The decisions of strategic managers matter to firm actions. The cognitive information-processing model clearly links managerial attention to managerial action (Barr, Stimpert, & Huff, 1992; Dutton & Jackson, 1987; Hambrick & Mason, 1984; Thomas et al., 1993; Thomas, Gioia, & Ketchen, 1997) while specific research has identified managerial attention as an important influence on firm innovation outcomes (e.g. Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007).

An information processing view of decision-making emphasizes how increased information can be beneficial to strategic decisions, affecting innovation outcomes. Exposure to external knowledge within its relevant environment influences decision-making (March & Simon, 1958b) future capability development (McGrath, MacMillan, & Venkataraman, 1995) as well as innovation (Ahuja & Katila, 2004; Rosenkopf & Nerkar, 2001; Yadav et al., 2007). The information processing perspective focuses on the importance of information availability to decision makers (e.g. Daft & Weick, 1984). More information means more raw materials managers can use in understanding (Knight & McDaniel, 1979) emerging and ambiguous strategic events in the environment. Strategic managers who have more information available are in a better position to cope with strategic decisions (Eisenhardt, 1989). Senior manager perception of environmental change influences organizational adaptation (Strandholm, Kumar, & Subramanian, 2004). The variety and breadth of information available to senior management has been found to increase accuracy in managerial perception (Sutcliffe, 1994) and reduce the perception of an event as a threat (Anderson & Nichols, 2007). Daft, Sormunen & Parks (1988) found that high information use strongly influenced strategic interpretation and that attention to a wide array of information influenced a positive interpretation of strategic issues. Managers, who recognize that there is more to be learned about an issue, engage in more data gathering to improve clarity and understanding (Knight & McDaniel, 1979). Managers who use more information generally perform better (D'Aveni & MacMillan, 1990; Eisenhardt, 1989).

Strategic advantage may be dependent upon the information available to senior management (Hambrick, 1982). High information availability can help managers gain insight into the business environment, understand problems and foster creativity (Vandenbosch & Huff, 1997). Diversity of managerial attention to environmental elements has been linked to a firm's strategic posture (Levy, 2005). Kaplan et al (2003) and Eggers and Kaplan (2008) found that managerial attention to a new technologies preceded innovation adoption. Yadav et al (2007) found that managerial attention which was oriented to the external environment and the future affected the detection and rate of innovation adoption. A wider breadth of managerial attention indicates a wider exposure to new knowledge, and it is only through such exposure that Potential Absorptive Capacity can become Realized Absorptive Capacity (Zahra & George, 2002). Such a wider breadth of managerial attention is more likely to expose senior management to external information (Yadav et al., 2007) such as new technologies (Eggers & Kaplan, 2008; Kaplan et al., 2003 1301) that are relevant to the firm's innovation activities. To explain this argument in plainer terms, the more broadly you are exposed to new information, the more likely you are to new identify opportunities. Based upon these arguments, I hypothesize:

H3: The Breadth of Managerial Attention is positively related to a firm's Explorative Innovation Outcomes.

3.4 The Meditating Influence of Managerial Attention

The creation of new knowledge is fundamentally based upon the recombination / synthesis of existing knowledge and new knowledge in new ways (e.g. Fleming & Sorenson, 2001; Hargadon & Sutton, 1997; Henderson & Cockburn, 1994; Henderson & Clark, 1990; Kogut & Zander, 1992; Schumpeter, 1939). Such re-combinations have been referred to as a second order competence (Rosenkopf & Nerkar, 2001). The success of the recombination process is affected by the knowledge available for recombination as influenced by the knowledge search process (Cyert & March, 1963; Katila & Ahuja, 2002; March & Simon, 1958a; Nelson & Winter, 1982; Stuart & Podolny, 1996; Winter, 2000). Whereas local search starts with knowledge the firm is familiar with, and is likely to add recombinatory possibilities near the firm's existing knowledge, exploratory search begins beyond the boundaries of the firm and is likely to add recombinatory possibilities more distant from the firm's existing knowledge (e.g. Ahuja & Katila, 2004; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). By concentrating on local search, firms generate knowledge in similar technologies which is potentially detrimental to long term innovative outcomes (Fleming, 2001; George et al., 2007) and exploratory innovative outcomes (Rosenkopf & Nerkar, 2001; Stuart & Podolny, 1996). Concentrating on familiar technologies can preclude the identification of useful technologies that may be technologically distant or such concentration may exhaust the set of useful combinatorial possibilities (Fleming & Sorenson, 2001)

Both individual and organizational processes facilitate local search. At the individual level, local search is the result of the bounded rationality and cognitive biases of decision makers who are prone to base future R&D decisions on historic R&D activities (Nelson & Winter, 1982; Stuart & Podolny, 1996). At the organizational level, the operating of routines facilitate local search (Cyert & March, 1963; Nelson & Winter, 1982; Stuart & Podolny, 1996). The effects of bounded rationality, cognitive biases and organizational routines closely link a firm's core technical knowledge structure and its innovative outcomes through the function of local search.

The processes that initiate exploratory search are different from those that perpetuate local search. Ahuja and Katila (2004) found that technical exhaustion and geographic expansion were two triggers that initiated exploratory search. Ahuja and Katila (2004) focus their study at the firm level and therefore do not address the mechanisms within the firm which triggers exploratory search. Chen and Miller (2007) more directly address this mechanism in their study of the determinants of R&D search intensity. In this study, aspiration level triggers (Greve, 1998; Lant et al., 1992) are the situational elements that impact organization level R&D expenditures. Chen and Miller (2007) base their study on Ocasio's (1997) underlying work on the attention based view of the firm and the impact of aspiration failure on managerial attention (Greve, 1998; Lant et al., 1992). In these studies, the role of managerial attention on exploratory search is pronounced but not directly addressed. Local search clearly ties a firm's core technical knowledge to its innovative outcomes. However, exploratory search that crosses boundaries and identifies new information available for recombination is initiated by mechanisms that operate through managerial attention. The combination of new knowledge with the firm's core technical knowledge leads to the development of new technological capabilities (e.g. Ahuja & Lampert, 2001; Kogut & Zander, 1992) which have been found to affect both the quantity and impact of a firm's long term innovative activity (George et al., 2007). The incorporation of new knowledge is influential in the generation of innovation and the importance of the innovation created (Ahuja & Lampert, 2001; Galunic & Rodan, 1998; George et al., 2007; Henderson & Cockburn, 1994; Katila & Ahuja, 2002; Phene et al., 2006; Rosenkopf & Nerkar, 2001). The incorporation of new knowledge comes from the firm's exploration across boundaries (e.g. Ahuja & Katila, 2004; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001) which is an attention based activity (e.g. Bantel & Jackson, 1989; Chen & Miller, 2007; Kaplan, 2008; Yadav et al., 2007).

Senior management plays an important role in the gathering and interpreting of external information (Rodan & Galunic, 2004; Smith et al., 2005), championing technologies (Howell & Higgins, 1990) and directing internal resources (Barker & Mueller, 2002). Unlike routine decisions, in strategic decisions (Child, 1972) such as exploratory innovation, the role of managerial cognition is emphasized (Bantel & Jackson, 1989; Cyert & March, 1963; Hambrick & Mason, 1984; March & Simon, 1958b). As the first step in the cognitive processing model, managerial attention is important to a firm's adoption of external innovations (Eggers & Kaplan, 2008; Kaplan, 2008; Yadav et al., 2007). A senior management with a wider breadth of attention is more likely to identify exploratory areas of knowledge potentially available for recombination with the firm's existing core technical knowledge. It is attention as the first stage of the attention-action model that leads to this new knowledge and thus exploratory innovation outcomes. To make this argument in plainer terms, for young high technology firms, senior management is in a critical position picking the avenues of growth the firm will pursue. Managers with a wider breadth of attention are more likely to identify new avenues of opportunity and direct firm resources in that direction. Based upon these arguments, I hypothesize:

> H4: The Breadth of Managerial Attention mediates the relationship of Core Technical Knowledge Structure on Explorative Innovation Outcomes.

3.5 Summary

In summary, this research addresses core resource structure and managerial attention as important antecedents of exploratory innovation outcomes. A firm's core technical knowledge represents the elements being recombined in the innovation process. Managerial attention represents the role of cognition in identifying potentially beneficial recombinations and exploring potential sources of new knowledge available for recombination. The model links the resource based and cognition literatures to argue that the structural elements of a firm's Core Technical Knowledge influences Managerial Attention and that Managerial Attention mediates the core technical knowledge structure – exploratory innovation relationship. This research addresses two fundamental research questions: First, 'What is the influence of a firm's core technical knowledge structure on managerial attention?' and second, 'What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes?' The following chapter develops the methodology to test these hypotheses.

4. METHODOLOGY

4.1 Overview

In the knowledge-based perspective, knowledge is the most strategically important of the firm's resources. Heterogeneous knowledge bases are considered the main determinants of performance differences among firms (Grant, 1996). The underlying knowledge of a firm has been conceptualized as stock of knowledge assets (Dierickx & Cool, 1989), which can also be conceptualized as a portfolio of knowledge resources. DeCarolis and Deeds (1999) used the biotechnology industry as a setting to examine the influence of the stock of organizational technical knowledge on firm performance. They measured the stock of an organization's technical knowledge using products in the pipeline, patents and article citations. While this study found the firm's stock of technical knowledge important to firm performance, it did not consider the influence of the structure of that stock of that knowledge. Henderson and Clark (1990) pointed out the importance of considering the relationship of component elements when dealing with product innovations and there is evidence that the structure of the stock of a firm's technical knowledge is important to knowledge innovations (Fleming, 2001; Fleming & Sorenson, 2001; Lin et al., 2006; Wu & Shanley, 2008).

In addition to the stock of a firm's knowledge available for recombination and thus innovation, managerial attention is important as it is central to the identification of external knowledge potentially available for recombination and thus likely to be influential on exploratory innovation outcomes (e.g. Bantel & Jackson, 1989, Yadav, 2007 #1496; Kaplan, 2008; Rosenkopf & Nerkar, 2001; Zahra & George, 2002). However, Ocasio (1997) in developing his attention based view of the firm hypothesized that a firm's unique resources would be an important influence on managerial attention. In this research I examine the relationship of a firm's core technical knowledge structure and managerial attention on firm exploratory innovation. This chapter explains the research setting, sample creation, variables and analytic methodology used.

4.2 Domain and Research Setting

The proposed model tests the impact of a firm's core technical knowledge structure on managerial attention; and the impact of managerial attention on exploratory innovation. An appropriate research setting to test this model would be characterized by 1) a senior management team that is intimately involved with the firm's core technical knowledge and 2) an industry in which innovation is critical to firm performance. These conditions suggest that an appropriate population would be young high technology firms. In younger firms, the role of senior management is more influential in setting the strategic direction of the firm and in the firm's innovative activities (Helfat & Peteraf, 2003). Younger firms are typically more entrepreneurial in structure and strategy and are heavily influenced by the top management team. Further, younger firms are less likely to have strategic decisions influenced by routinization. In addition, high technology industries are characterized by dynamic technological environments where survival is dependent upon frequent new product development and commercialization. Therefore, young, high technology companies provide a rich setting for the testing of the model.

Data collection of the independent and dependent variables will be from public sources so the industry context and availability of public data are a consideration. With respect to measures of exploratory innovation (the dependent variable) and a firm's core technical knowledge (independent variables), patent data affords an opportunity to richly capture these constructs. Due to its inherently abstract nature, the measurement of technical knowledge is difficult. For science-based companies, measures based upon a firm's patents have been extensively used to measure aspects of a firm's core technical knowledge (e.g. Dutta, Narasimhan, & Rajiv, 2005; Fleming & Sorenson, 2001; George et al., 2007; Hall et al., 2001; Henderson & Cockburn, 1994). With respect to managerial attention (independent variable), when direct access to top management is unavailable, managerial attention has often been examined through the use of secondary sources available from public companies, specifically the annual letter to shareholders in the firm's annual report (e.g. Abrahamson & Hambrick, 1997; Cho, 2006; Kaplan, 2008; Kaplan et al., 2003; Levy, 2005). Due to these requirements, it is important that the sample be comprised of public firms in a science based knowledge intensive industry that extensively utilizes patent protections. Previous studies have demonstrated that patent practices, patent effectiveness and patent propensity varies significantly across industries (e.g. Cockburn & Griliches, 1988; Levin, Klevorick, & Nelson, 1987). These problems have been mitigated by focusing on a single industrial context where these factors are more stable (e.g. Ahuja & Katila, 2001; Katila & Ahuja, 2002).

The general characteristics derived above, calls for a sample of young public companies in a science based knowledge intensive industry that extensively utilizes patent protections. The biotechnology industry presents a unique environment that meets these criteria. Biotechnology is a knowledge intensive industry based on highly complex and specific understandings that continue to evolve. The biotechnology industry is based upon multiple technologies – molecular biology, immunology, genetics, combinatorial chemistry and bioinformaticis (Sorensen & Stuart, 2000), involving multiple different disciplines (Christensen, 2003) and requiring combinatorial knowledge (Quere, 2003). Firms often possess unique knowledge assets identified in the form of process or molecule patents. Patenting is important in the biotechnology industry as patents represent the intellectual capital of the industry and protect core intellectual property (Shan & Song, 1997). Lerner (1994) demonstrated that the scope of a patent increases the valuation of biotechnology firms. As a relatively young industry, biotechnology firms are often small with limited financial resources, limited staffs and technically involved senior management. As such, these firms are highly dependent upon the knowledge and expertise of their top management. These characteristics have led researchers to focus on the biotechnology industry as an appropriate context to examine theories of innovation (e.g. Phene et al., 2006; Sorensen & Stuart, 2000). Thus, study of the biotechnology industry best supports the purpose of this dissertation.

4.3 Sample Creation

In order to estimate causality, it is necessary that the sample lend itself to the collection and analysis of panel data. In an ideal setting, firms would be observed at the point of their initial formation and thereafter. However, due to the data requirements above, this is not practicable. The earliest that secondary information is available to observe managerial attention in a firm is immediately post IPO. In order to examine the relative attention of an individual firm, the sample of firms should be experiencing a similar environment. To enable this criterion, the use of a biotechnology IPO cohort is most applicable to the identification of the causal relationships of interest.

The biotechnology sample was made up of all those firms with an initial public offering in 1995 and 1996. The sample originally included only 1996 IPOs due to the availability of trade journals that began publishing biotechnology IPO information in 1996. However, in order to increase the sample and the number of shareholders letters available, firms with an IPO in 1995 were added. Four methods were used to identify biotechnology IPO cohorts for the years 1995 and 1996. First, the SDC Platinum database by Thomson Reuters was used to identify all U.S. common stock new public issues of biotechnology companies. BioWorld Financial Watch is a weekly market data and news service focused on the business side of the biotechnology industry. BioWorld Publishing Group started this industry weekly in

1993. Starting in 1996, BioWorld published a quarterly stock report which listed all publicly traded biotechnology firms. These quarterly reports were collected and differences between the quarterly reports were used to identify new public companies for the 1996 period. As a second method, using the Factiva database, the trade journals, BioWorld Financial Watch, BioWorld Today and BioWorld Week were searched for articles with 'IPO' in the headline or lead paragraph. Trade journals are often used to identify sample participants (e.g. Ahuja & Katila, 2004; Williams & Young, 2006). Companies identified in these articles were compared to the list of companies identified above. As a third method, Willams and Young (2006) also sought to identify all biotechnology IPOs from 1996 forward. Their search was conducted using trade journals and online resources. The list of companies identified by Williams and Young (2006) was compared with the companies identified by the two methods above. Third, in order to confirm the appropriate cohort year the company belongs to, the firm's IPO date was determined through a search of the SEC's online resources, EDGAR Online. These methods identified 33 IPOs in 1995 and 39 IPOs in 1996. Of these 72 companies, no additional information was able to be located on 17 of them. Twelve were eliminated from the sample because their fundamental business did not involve innovation in biotechnology drug discovery ie diagnostics and device manufacturing and thus represented a different industry dynamic (Ahuja & Katila, 2001; Katila & Ahuja, 2002). Finally, three companies were eliminated because although public, they did not publish a single shareholders letter from 1996-2001. After reduction for these reasons, the sample included 40 biotechnology companies involved in fundamental research and discovery and active in the use of patent protections. These 40 companies were tracked as a cohort from 1996 – 2006. This data collection structure generates 1) six years of longitudinal shareholder letter collection for a possible 240 'firm/year' observations of managerial attention, 2) six years of firm patent portfolio information (1996-2001) and 3) 10 years of firm innovation information 1996-2006. Of the potential 240 shareholders letters available for collection, 175 were able to be collected. The primary reasons for this reduction were 1) mergers / acquisitions 2) business failure and 3) management teams not including a shareholders letter in their annual report.

4.4 Independent Variables

The present study examines two sets of independent variables; structure of a firm's core technical knowledge and the breadth of managerial attention. The variables were operationalized using measures adopted from relevant literature. The following two sub-sections describe how the independent variables are measured as well as the rationale behind the measures. Measures of major variables are presented in Table 4.1, 4.2, 4.7 and 4.8

4.4.1 Core Technical Knowledge

The characteristics of the patents held by a firm are a common method used to measure the characteristics of a firm's technical knowledge (e.g. DeCarolis, 2003;

DeCarolis & Deeds, 1999; McGrath & Nerkar, 2004; Miller, 2006; Phene et al., 2006; Sorensen & Stuart, 2000). Patenting is important in science intensive industries, including the biotechnology industry (e.g. Hall & Bagchi-Sen, 2002; Phene et al., 2006; Shan & Song, 1997).

A U.S. patent is the grant of a property right to an inventor, issued by the United States Patent and Trademark Office (USPTO). The term of a new patent is 20 years from the date on which the application for the patent was filed. A patent grants a monopoly right to exclude others from making, using, offering for sale, or selling the invention in the United States. Patents have been granted in the US since the 18th century (USPTO, 2007). The USPTO maintains a publicly available full text database of U.S. patents that dates from 1976 (USPTO, 2007). The USPTO database has been widely used in strategy research. (e.g. DeCarolis & Deeds, 1999; Fleming & Sorenson, 2001; Hall et al., 2001; McGrath & Nerkar, 2004; Miller, 2006; Phene et al., 2006; Sorensen & Stuart, 2000).

In order to obtain a patent, an inventor must disclose extensive information on the invention to the USPTO. This information includes 1) the prior patents that the current application builds upon and 2) the claim or series of claims that define in technical terms the novelty, innovation, usefulness and industrial application of the invention (USPTO, 2007). A patent applicant is under legal obligation to disclose any prior patents they are aware of that the current application relies upon. This is required since prior patents represent existing knowledge which the innovation makes use of. Citation of prior patents limits the scope of the property rights awarded to the applicant patent and helps to identify new knowledge created by the patent (Walker, 1995). The patent examiner, an expert in the area of application, has final say over citation to prior patents (Hall et al., 2001).

The USPTO has established the US Patent Classification System (USPCS) for organizing all patent documents by common subject matter based upon the claims made. This system uses major divisions called 'classes' and minor components called 'subclasses.' A class is used to define a general technological area and is mutually exclusive to other technological areas. A subclass is used is used to define a process, structural feature or functional feature of the technology within the scope of the class. For example, Algos, a biotechnology company, owns patent number 5,919,826 with the title 'Method of alleviating pain'. This patent has a primary classification of 514 and a primary sub-classification of 629. The USPCS defines primary classification 514 as 'Drug, Bio-Affecting and Body Treating Compositions'. Primary sub-classification 629 is defined as:

> 'Designated Organic Active Ingredient Containing (DOAI):
>
> - which includes a compound containing nitrogen in a form other that as nitrogen in an inorganic ion of an addition salt, nitro or nitroso.
>
> - including carboxamides which have the grouping RN wherein R is either a radical having carbon bonded directly to the C=O or is hydrogen and wherein any substituent attached to nitrogen will be referred to as E.
>
> -wherein the carboxylic acid residue (R) does not contain a ring.

- wherein the carboxylic acid residue (R) is from a lower fatty acid, i.e., a fatty acid of one to seven carbons containing a C of the carboxy group.' (USPTO, 2009)

The USPCS uniquely identifies more than 400 classes and over 150,000 subclasses (Hall et al., 2001; USPTO, 2007). Every patent has one primary class (PC) and one primary subclass (PS) identifier called a 'principal mandatory classification'.

The use of patents to capture a firm's technical knowledge is more than simple convenience or access to data. Studies have confirmed empirical links between a firm's patents and other measures of firm capabilities including the primary business the firm operates in (Patel & Pavitt, 1997) as well as its' research and development activities (Jaffe & Trajtenberg, 2002). Patents have been used extensively to capture the technological knowledge and capabilities of firms. Researchers have used patent data to explore a firm's core technical competence (Henderson & Cockburn, 1994; Patel & Pavitt, 1997), estimate innovation importance (Fleming & Sorenson, 2001; Hall et al., 2001; Hall & Bagchi-Sen, 2002), measure technical exploration and exploitation (Ahuja & Katila, 2004; Argyres & Silverman, 2004; Rosenkopf & Nerkar, 2001), examine knowledge spillovers (DeCarolis & Deeds, 1999; Henderson, Jaffe, & Trajtenberg, 2005; Jaffe & Trajtenberg, 1993), identify linkages between technologies (Fleming & Sorenson, 2001; George et al., 2007; Stuart & Podolny, 1996), examine technical diversity (Miller, 2006), measure technical innovation (Dutta & Weiss, 1997; Fleming & Sorenson, 2001; George et al., 2007; Phene et al., 2006; Sorensen & Stuart, 2000) and quantify technology portfolio strategy (Lin et al., 2006; Lin & Chen, 2005). The use of patent derived measures is well established in studies of firm technical knowledge.

The use of patents in the measurement of firm knowledge is not without limitations. Knowledge has been conceptualized as being both explicit and tacit (Grant, 1996; Nonaka, 1994). Explicit 'refers to knowledge that is transmittable in formal, systematic language' where tacit knowledge is an understanding that is difficult to formalize and transmit (Nonaka, 1994, p16). Both tacit and explicit knowledge are theoretically and empirically important to organizational outcomes (Grant, 1996; Nonaka, 1994). As Nonaka (1994) pointed out, new knowledge creation is a function of both tacit and explicit knowledge interaction. Due to the nature of explicit knowledge, it is more easily measured than tacit knowledge. However, as Mowery, Oxley and Silverman (1996) point out, explicit knowledge, represented by patents, and tacit knowledge are closely linked and complementary. This is born out in research that has found similar results using measures of tacit knowledge vs patent derived measures (Patel & Pavitt, 1987).

The use of patents as the basis for measuring core technical knowledge is well supported in the literature. The following measures use patents as the basis of calculating two dimensions of a firm's core technical knowledge structure; the degree of concentration and the ease of recombination.

Concentration of Core Technical Knowledge

The importance of concentration in a firm's core technical knowledge flows out of underlying theories of core competency in the strategy literature (Prahalad & Hamel, 1990). A firm may have technical knowledge across several areas, thus representing a "portfolio of technical knowledge". A measure of a firm's concentration across those areas would capture the distribution of those areas of expertise for a particular firm. The relative concentration in a firm's technical knowledge portfolio represents a clear distinction between a firm's core and peripheral knowledge (Lyles & Schwenk, 1992; Prahalad & Hamel, 1990). Scholars interested in capturing firm technical knowledge have created categories of knowledge and estimated concentration within these categories.

Henderson and Cockburn (1994; 1996) examined drug discovery, as a 'component competence' of pharmaceutical firm operations. The authors used the stock of the firm's patents, within individual research program areas as a measure of component competence. Firms with a greater stock of patents in a program area had a greater component competence in that area. Categorization by program area is generally not practicable without direct access to company records. Also, summative measures at the program level are unable to capture the importance of similar knowledge separated structurally into different research programs. In order to address such concerns, researchers began to use the information available from the USPTO to generate categories of firm knowledge and estimate knowledge concentration by category.

Patel and Pavitt (1997), using a sample taken from the pharmaceutical industry, summarized the USPTO class/subclass system into a smaller set of categories and then calculated a firms patent share within that smaller set of categories. The patent share calculation indicated the relative importance to the firm of competencies within the summary category. For Patel and Pavitt (1997) knowledge categories were based upon the USPTO class/subclass system and knowledge concentration was based upon the number of firm patents within these categories. Patel and Pavitt's (1997) division of the USPTO classification into summary categories was necessitated by the multiple industry nature of their study and the breadth of the underlying USPTO classification system.

Trajtenberg, Henderson and Jaffe (1997) also utilized the USPTO's classification system but introduced the use of a Herfindahl type index to measure knowledge concentration. A Herfindahl index is typically calculated as: Concentration = $\sum^{j}_{1} S^{2}_{ij}$ where S_{ij} denotes the percentage of classifications received by category i within j total categories. The index ranges from 1/n to one. Higher values represent greater concentration. Based upon Trajtenber et al (1997), Hall, Jaffe and Trajtenberg (2001) used a Herfindahl type index as part of their decade long research program focused on US patent data, sponsored by the National Bureau of Economic Research (NBER). Within Hall et al's (2001) program of study, USPTO primary and subsidiary classifications were summarized into six main technological categories and 36 subcategories. These technical categories were used in calculation of Herfindahl type measures of technology concentration. Hall et al's (2001) use of a Herfindahl index and the availability of the underlying NBER data have made the use of this concentration measure common in studies of technical knowledge portfolios. (e.g. Ahuja & Katila, 2004; Argyres & Silverman, 2004; George et al., 2007; Hall et al., 2001; Lin et al., 2006; Lin & Chen, 2005; Trajtenberg et al., 1997).

Following this literature, I use a Herfindahl index calculated at the primary classification and the primary sub-classification levels to measure concentration as follows:

Primary Class Concentration (PCConc)= $\sum_{1}^{j} QPC_{ij}^{2}$ where '*QPC*' denotes the percentage of patents within primary classification *'i'* within a portfolio of *'j'* total primary classifications.

Primary Subclass Concentration (PSConc) = $\sum_{1}^{j} QPS_{ij}^{2}$ where '*QPS*' denotes the percentage of patents within primary sub-classification *'i'* within a portfolio of *'j'* total primary sub-classifications.

As an example, I turn back to the biotechnology company Algos. At year end 1999, Algos owned 18 patents distributed between three primary classifications, 14 in PC 514, three in PC 424 and one in PC 602. Algos was highly concentrated at the Primary Class level with its core technical knowledge 77.8% classified in PC 514. The Primary Class Concentration measure above for Algos's in 1999 was 63.6%. At the Primary Subclass level, these 18 patents were distributed across eleven categories with a maximum of six patents in a single Primary Subclass. The Primary Subclass Concentration for Algos in 1999 was 16.7% indicating a greater diversity at the Primary Subclass level than the Primary Classification level.

The Herfindahl index as a measure of concentration melds two concepts, the categories and the number of items summarized within the category. Fleming and Sorenson (2001), present a theory of innovation that is focused on the importance of the number of individual categories available for recombination in the innovative process, as opposed to the relative concentration within those categories. Their argument is that the greater the number of individual elements available for recombination, the greater the innovative possibilities. Fleming and Sorenson (2001) measured the number of individual elements in an innovation using the USPTO classification system and found the number of knowledge components available for recombination important in the innovation process. The number of unique primary classifications and primary sub-classifications represents at a high level the number of separate core technical knowledge elements that the firm has available for recombination in the innovation process.

Following Fleming and Sorenson (2001), I further measure concentration as the number of unique elements available for recombination at the primary classification and primary sub classification level as follows:

Number of Unique Primary Classes (#UqPC) $= \sum UPC_{ti}$ where 'UPC' represents a single primary classification where firm 'i' has an interest in at least one patent during time period 't'. This variable includes patents that the firm acquired through other means (merger / acquisitions / IP agreements).

Number of Unique Primary Sub-classes (#UqPS) $= \sum UPS_{ti}$ where 'UPS' represents a single primary sub-classification where firm 'i' has an interest in at least one patent during time period ‘t’. This variable includes patents that the firm acquired through other means (merger / acquisitions / IP agreements).

Returning to Algos as an example, at the end of 1999, the company held a unique knowledge position in three separate Primary Classifications and eleven separate Primary Sub-classifications. These knowledge areas represented the fundamental knowledge areas Algos had available for recombination in its innovative activities. The four concentration measures are summarized in Table 4.1.

Ease of Recombination

Ease of Recombination is a portfolio level measure of the degree to which a firm’s knowledge easily combines with other knowledge. This concept is similar to Fleming and Sorenson’s (2001; 2004) innovation level concept of coupling. Using patent data, Fleming and Sorenson (2001) found that the ease with which different knowledge bases combine at the innovation level was highly influential on innovation importance. Their measure of coupling was calculated in two steps. First the knowledge elements, making up an innovation, were examined for how many times they had previously been combined with other knowledge elements. This calculated a measure of recombination for an individual knowledge element. Second, for each innovation, this measure of recombination was summed based upon the knowledge elements that made up the innovation.

In order to calculate a measure of recombination of an individual knowledge element, Fleming and Sorenson (2001) calculated the relationship of all cross reference classifications for all patents the USPTO issued between May and June 1990. To accomplish this, they identified every cross-reference classification *i* used in a sample of previous patents. The sum of the number of patents that used classification i provided the denominator. The numerator was a count of the number of different cross-reference classifications that appeared with *i*. Fleming and Sorenson's (2001) formula for the Recombination for cross reference class *(i)* is:

$$\equiv Ei = \frac{Count\ of\ cross\ reference\ classes\ previously\ combined\ with\ i}{Count\ of\ previous\ patents\ in\ cross\ reference\ class\ i}$$

This measure increased as a particular cross reference classification combined with a wider variety of other cross reference classifications and therefore captured the relative ease with which a particular type of knowledge recombined with other forms of knowledge.

The second step created the measure of Coupling for a patent by aggregating the Recombination value for the all cross reference classifications within a patent. This was accomplished by summing the Recombination measure *(E)* for all cross reference classifications (l) assigned to patent *(i)* and adjusting for the number of cross reference classifications within a patent. Fleming and Sorenson's (2001) formula's for this Interdependence of a patent is:

$$\equiv MEi = \frac{Count\ of\ cross\ reference\ classification\ on\ patent\ i}{\sum_1^i Ei}$$

Through these measures, Fleming and Sorenson (2001) were able to estimate the relative ease of recombination of the knowledge elements that made up a single patent (innovation).

Fleming and Sorenson's (2001) methodology can be applied at the firm portfolio level with minor modification. Specifically, Fleming and Sorenson (2001) examine the relationship between knowledge components using the cross-reference classifications at the patent level. The logic is that because a single patent includes multiple cross reference classifications, the knowledge indicated by those cross reference classifications are related. However, the relationship of a patent's knowledge to other knowledge can also be established through the use of prior patent citations. The logic here is that because a subject patent cites a prior patent, the knowledge indicated is related. The use of prior patent citations is well established for generating measures of the relatedness of knowledge (e.g. Almeida, 1996; Almeida, Dokko, & Rosenkopf, 2003; George et al., 2007; Henderson et al., 2005; Jaffe & Trajtenberg, 1993; Phene et al., 2006; Sorenson, Rivkin, & Fleming, 2006; Tallman & Phene, 2007). Using the formulas presented by Fleming and Sorenson (2001) and a logic of prior patent citations, a portfolio level measure of Ease of Recombination can be estimated. In order to calculate this measure, it is first necessary to estimate the Ease of Recombination for the knowledge elements used in the biotechnology industry. Afterward, the Ease of Recombination of a firm's core technical knowledge can be estimated. These two steps are discussed separately.

It is not necessary to calculate the Ease of Recombination for all primary classifications in the USPTO classification system. The subset that it is necessary to calculate these values for are those primary classifications associated with the patents held by those companies in the sample. Any primary classification categories outside of this subset would not end up being used in calculations based upon the sample's patent holdings. Therefore, the first step in calculating the Ease of Recombination is to identify all unique primary classifications associated with the patents held by all the firms in the study. Once these unique Primary Classifications are determined, the next step is to identify related patents. In order to do this, the USPTO derived data prepared by Hall et al (2001), is used to identified all patents with the same primary classification. Then, prior patent citations are pulled and the Primary Classification of those citations are collected. Through this method, each unique Primary Classification in the sample is identified with the prior knowledge that it is related to due to prior patent citation. A schematic of this process can be found in Figure 1 for Primary Classification 514, which is one of the primary classifications Algos holds patents within.

From this information the Ease of Recombination for a single *PCi* can be calculated as:

$$\mathrm{E}\mathit{ase\ of}\ \mathrm{Re}\mathit{combination}\ P\mathrm{C} = \mathrm{E}R.P\mathrm{Ci} = \frac{\mathrm{C}\mathit{ount\ of}\ P\mathrm{C}\ \mathit{previously\ combined\ with}\ P\mathrm{Ci}}{\mathrm{C}\mathit{ount\ of}\ \mathit{previous\ patents\ in}\ P\mathrm{Ci}}$$

Following Algos and Primary Classification 514 as an example, based upon the USPTO data available through 2002 (Hall, 2008), a total of 70,613 patents use 514 as a primary classification and 339 other primary classes are linked through prior patent citations to it. The Ease of Recombination for Primary Classification 514 measures .0048 = (339 cross citation primary classes / 70,613 patents).

After calculating the Ease of Recombination for all unique Primary Classes contained in the sample, the Ease of Recombination of a specific portfolio of patents *(l)* at a point in time *(t)* is calculated at the Primary Class level as:

$$\text{E}ase\ of\ \text{Re}combination\ Portfolio = \text{E}R_{lt} = \frac{\text{C}ount\ of\ Patents_t}{\sum_{1}^{l} \text{E}R.P\text{Ci}}$$

This section set forth a methodology to measure the Ease of Recombination of a firm's core technical knowledge portfolio. Measures are summarized in Table 4.1. In addition to measuring the structure of a firm's core technical knowledge as an independent variable, this study also measures managerial attention.

4.4.2 Managerial Attention

Techniques to examine managerial attention have been evolving. Early studies focused on direct observation and time and task measurements (e.g. Sproull, 1984). These techniques inherently limited the scope of these studies as survey and interview methods are generally not able to capture a wide sample of a senior management population or be conducted longitudinally. Use of accounting based proxy variables such as marketing expenditures have also been used (e.g. Durand, 2003) but these introduce the potential for intervening unobserved variables between the attention construct and the proxy variable. Others have applied managerial demographics as a proxy for cognition (e.g. Bantel & Jackson, 1989; Hambrick & Mason, 1984). However, demographics are relatively fixed whereas changes in the environment can shift attention over time (Hambrick, Geletkanycz, & Fredrickson, 1993; Kaplan, 2008). It is reasonable to assume that the most reliable place to find information on managerial attention would be statements made by the senior management. As noted above, survey and interview methods have scope and longitudinal limitations, further, statements by senior managers in speeches, interviews and conferences calls are ad hoc, subject to retrospective bias and not available in comparable forms for all firms across time. To address these concerns, scholars have turned to using the Letter to Shareholders in the Annual report as a source for measurements of senior management attention (Abrahamson & Amir, 1996; Abrahamson & Hambrick, 1997; Barr et al., 1992; Cho & Hambrick, 2006; D'Aveni & MacMillan, 1990; Duriau, Reger, & Pfarrer, 2007; Eggers & Kaplan, 2008; Kaplan, 2008; Kaplan et al., 2003; Levy, 2005).

The use of the Letter to Shareholders and content analysis in general is built upon the Whorf-Sapir hypothesis which states that the cognitive categories through which people attend to their world are embedded in the words they use (Sapir, 1944; Whorf, 1956). The Whorf-Sapir hypothesis is the underlying logic for developing what Huff (1990) referred to as 'maps of attention.' Use of the Letter to Shareholders in the Annual Report to measure managerial attention has a number of strengths over other sources of corporate information. Osborne Stubbart and Ramaprasad (2001) cited the lack of retrospective sense making. Other scholars have emphasized the role of senior management in the preparation of the document and the responsibility indicated by signing the letter (Barr et al., 1992; D'Aveni & MacMillan, 1990; Duriau et al., 2007). Abrahamson and Amir (1996) cited the relative freedom available to senior executives in the Letter to Shareholders as opposed to the regulatory restrictions on the Management's Discussion and Analysis in the 10K. Due to these strengths, Letters to Shareholders are considered a 'particularly good window into major issues and arenas that are of interest and concern to senior managers' (Levy, 2005, p 804), revealing managerial attention patterns (D'Aveni & MacMillan, 1990; Duriau et al., 2007).

The use of the Letter to Shareholders is not without criticism. Two primary criticisms are that the Letter to Shareholders may be prepared by a public relations specialist (Abrahamson & Hambrick, 1997) and may suffer from bias in the attribution of actions and outcomes (Barr et al., 1992). Abrahamson and Hambrick (1997) argue that there is sufficient anecdotal evidence of a high level of top management involvement in the drafting of these letter. Several studies have examined the patterns of causal attribution in shareholder letters and found evidence that these attributions were better explained by cognitive processes such as positive outcome self attribution, negative outcome other attribution biases (Huff & Schwenk, 1990) than by impression management theories (Bettman & Weitz, 1983; Clapham & Schwenk, 1991; Huff & Schwenk, 1990) supporting the position that the Letter to Shareholders represents a valid indicator of top management cognition. Fiol (1995) generally agreed with this position but concluded tentatively that non-evaluative statements (attributions of control) were more likely to represent managerial cognition and that evaluative statements (positive negative) were more likely to represent impression management attempts. This concern is not an issue in this study because the outcomes of managerial attributions are not under examination. Other studies have demonstrated evidence of construct validity for Letter to Shareholder derived measures of managerial cognition by testing the theoretical relationship between those constructs and other variables (Abrahamson & Amir, 1996; Cho & Hambrick, 2006; D'Aveni & MacMillan, 1990; Daly & Pouder, 2004; Duriau et al., 2007). The Letter to Shareholders in the annual report is used to develop measures of managerial attention applied in this study.

Breadth of Managerial Attention

The model intends to capture the "breadth of managerial attention". As explained in Chapter 3, breadth of managerial attention might be influenced by the firm's core technical knowledge. Breadth of managerial attention may also impact a firm's exploratory innovation. Lexical based measures of attention are based upon the Whorf-Sapir, as explained above. In this hypothesis, "word use" indicates a direction of attention while "frequency of use" indicates intensity of attention (Huff, 1990). Based upon this logic Abrahamson and Hambrick (1997) used commonality of word use to develop two measures of managerial attention, Lexical Commonality and Lexical Density. Lexical Commonality is a construct used in linguistic research that measures the average frequency of word use across a set of documents. In its application, it measures the intensity of concepts being used by a firm as compared to the use of those concepts by competitor firms. Abrahamson and Hambrick's (1997) example of a simple lexical commonality calculation is reproduced in Table

4.3. In this example, three firms only use four words. The number of firm that uses a word determines the word's commonality. For example, all three firms use 'sales' so it has a word commonality of 100%. Meanwhile, one firm only uses 'assets' so it has a word commonality of 33%. The number of times each word is used in an individual letter is multiplied by the word's commonality and the sum of these calculations across all words used in a shareholders letter calculates the Lexical Commonality for the letter. In the example, firm 1 mentions 'sales' three times, 'assets' four times and 'costs' five times. These words have commonalities of 100%, 33% and 100%, respectively; calculating the letter's commonality as (3x100)+(4x33)+ (5*100)/ (3+4+5) =78.

Lexical Commonality is applied here as a measure of the breadth of managerial attention. Senior managers that attend more intensely to more issues attended to by their peers will have a higher Lexical Commonality score while those senior managers who attend more superficially or to a narrow or different set of issues will have a lower Lexical Commonality score.

Lexical Commonality for a single shareholder letter is calculated in three steps: 1) the percentage of all shareholders letters that use a word determines a word's 'commonality across letters'. 2) the number of times each word is used in a single letter is multiplied by the word's commonality across letters 3) for a single letter the individual word score are summarized for all the words in a letter. The formula for this calculation is:

$$Lexical\ \mathrm{C}ommonality = \mathrm{C}ommonality = \sum_{i}^{n} Fw_i \times Q_w$$

Where ‘n’ represents the number of words in a shareholders letter, and ‘F’ represents the frequency of use of word ‘w’ occurring in shareholders letter ‘i’ and ‘Q’ represents the proportion of shareholders letters that also used word ‘w’. Keegan and Kabanoff (2008) recently validated this measure in a study of industry and sub-industry level managerial discretion.

Abrahamson and Hambrick (1997) found that the Lexical Commonality measure would have a tendency to overweight words that appeared in only a small portion of the letters being analyzed. To address this weakness, they developed a second measure, Lexical Density which measured word sharing without reference to word frequency in a single shareholders letter. Lexical Density measures the occurrence (binary) of a concept (word) used by a firm as compared to its maximum possible occurrence in all competitor firms. An example of a simple Lexical Density calculation shown in Table 4.4. In this example, three firms use only four words. The potential number of binary combinations is determined based upon the number of firms, in this case three. Using the combination formula, $\frac{n!}{k!(n\text{-}k)!}$, the potential binary (k=2) combinations across (n=3) firms totals 3 potential combinations. For any specific word, the actual combinations are calculated based upon the number of firms that used that word. Using the example in Table 4.4, the word ‘Margins’ was used by 2 firms. Using the combination formula (n=2, k=2) there is one possible combination. Therefore, the word Margins was used in 1 actual combination out of 3 possible combinations for a Lexical Density ratio of .33. The Lexical Density for any shareholders letter then is the summation of the Lexical Density of the words that make up that letter.

Lexical Density is measured as:

$$Lexical\ Density = Density = \sum_{1}^{n}\left(\frac{\mathrm{S}Aw}{\mathrm{S}Mw}\right)$$

Where '*SAw*' represents the number of firms that share word 'w' and *'SMw'* represents the potential maximum number of firms that could share word *'w'.* Keegan and Kabanoff (2008) recently validated Lexical Density in a study of industry and sub-industry level managerial discretion. Similar to Abrahamson and Hambrick (1997) as well as Keegan and Kabanoff (2008), Lexical Density is applied in addition to Lexical Commonality as measures of the breadth of managerial attention. Managers that highly attend to those issues also attended to by their peers will have a higher Lexical Density score while those managers who attend to a more narrow or different set of issues will have a lower Lexical Density score.

This section defined two measures for the breadth of managerial attention. Lexical Commonality and Lexical Density, are based upon word level comparisons of the language used in the shareholders letters. A summary of these measures can be found in Table 4.2. The following develops the measures of exploratory innovation used in this study.

4.5 Exploratory Innovation

Thomas and McMillan (2001) as well as Lin and Chen (2005) reviewed prior research on innovation (R&D) performance measures. They identified bibliographic measures as a primary means of measuring innovation. Bibliometric measures use scientific publication or patent data to estimate the structure and quality of a firm's knowledge portfolio or the level and quality of a firm's innovative output (e.g. DeCarolis & Deeds, 1999; Fleming & Sorenson, 2001; Hall et al., 2001; Hall, 1992). Bibliometric measures have demonstrated strong linkages between actions or processes and innovation outcomes (e.g. Fleming, 2001; Fleming & Sorenson, 2001; Fleming & Sorenson, 2004; Sorensen & Stuart, 2000; Sorenson et al., 2006). Bibliometric measures are used to examine exploratory innovation performance in this study.

The granting of a patent by definition means the creation of a technological innovation with utility (Walker, 1995). However, the novelty created can vary in its relationship to the firm's existing core technical knowledge. An innovation may rely on the same underlying knowledge that encompasses the firm's core technical knowledge or vary in degree of utilizing new to the firm knowledge. The incorporation of new knowledge has been found important in the creation of innovation and the importance of the innovation (Ahuja & Lampert, 2001; Galunic & Rodan, 1998; George et al., 2007; Henderson & Cockburn, 1994; Katila & Ahuja, 2002; Phene et al., 2006; Rosenkopf & Nerkar, 2001). The incorporation of new knowledge comes from the firm's exploration across technical boundaries. (e.g. Ahuja & Katila, 2004; Katila & Ahuja, 2002; Rosenkopf & Nerkar, 2001). Innovation across this boundary is incorporated in the dependent measures; Number of New Primary Subclasses (NoNPS) and New Primary Class (NPC) . These measures are discussed individually.

New Primary Subclass and New Primary Class

The Number of New Primary Subclass (NoNPS) measures the introduction of a new primary subclass into the firm's core technical knowledge portfolio. This represents the firm's exploration across a technological boundary (e.g. Ahuja & Lampert, 2001; Rosenkopf & Nerkar, 2001) but within an area the firm has a defined level of competence i.e. within a USPTO primary classification the firm holds prior patents in. Similar measures have been used by Rosenkopf and Nerkar (2001) and Ahuja and Lampert (2001) to identify a firm's introduction of a 'Novel Technology'. As applied here, NoNPS estimates the degree to which a firm develops new technologies within general areas of expertise it already holds. NoNPS, in any year, is the sum of the new to the firm primary subclasses. NoNPS is calculated as:

$$NoNPS = \Sigma \, NPS_{ti}$$

Where NPS represents an application date within time period *'t'* by firm *'i'* to the USPTO for a patent in a new to the firm primary subclass. This measure estimates the firm's explorative innovation across a technological boundary but within a general level of expertise.

As opposed to the creation of a new patent that is within a primary class the firm already has experience with, the measure New Primary Class (NPC) indicates the firm's exploratory crossing of technological boundaries where the firm has a lower degree of expertise. As calculated, NPC is a binary variable indicating if a firm created a patent with a primary classification that was new to the firm. NPC is calculated as:

NPC =1 if $(PC_t \neq PC_{t-1})$

NPC = 0 if $(PC_t = PC_{t-1})$

Where '*PC'* represents the portfolio of unique primary classifications at time period 't'. NPC only is calculated upon patents the firm creates and does not include patents that the firm acquired through other means (mergers/acquisitions/IP agreements). NPC is a binary variable due to the rarity with which firms create patents that cross into new primary classifications. A summary of these measures are listed in Table 4.7.

The two dependent variables measure the creation of innovations that cross different technological boundaries. NoNPS measures the creation of innovations within the firm's general area of knowledge while NPC measures the creation of innovations that extend beyond the firm's general area of knowledge.

4.6 Control Variables

Control variables are used in an attempt to account for potential spurious relationships between the independent and dependent variables. Three areas are identified where control variables are necessary; Firm size, prior patents and time.

Controls for firm size are common in studies of innovation. The relationship of firm size to innovation goes back to the work of Schumpeter (1942) who proposed that large firms generated a disproportionate level of innovation. Scholars have put forth a number of explanations for this effect including the scale economics in R&D and the improved ability of larger firm to appropriate returns on innovation (Cohen & Klepper, 1996a, b; Freeman & Soete, 1997). Hall and Bagchi-Sen (2002) concluded that firm size for Canadian Biotechnology companies was a barrier to innovation. Following Lin and Chen (2006; 2005), I operationalize firm size as the natural log of total assets.

Two arguments call for the inclusion of prior patents as a control. First, the measures used, in this study, to estimate the characteristics of a firm's core technical knowledge portfolio use the USPTO's classification system to characterize separate knowledge components. However, patents themselves represent individual and unique knowledge components (Jaffe & Trajtenberg, 2002) that can be combined in the creation of new innovations (Argyres & Silverman, 2004). In order to isolate the effect of the structure of the firm's core knowledge portfolio, the level of prior patents needs to be controlled for. Second, firms are likely to have different thresholds regarding patenting. Firms with a lower cost of patenting or a lower quality threshold, which an innovation much past, are likely to engage in a higher level of patenting activity (Sorensen & Stuart, 2000). To address these issues, the number of patents a firm holds is introduced as a control. Firm Patent Stock is measured as the natural log of the number of patents assigned to the firm (Argyres & Silverman, 2004; Phene et al., 2006; Sorensen & Stuart, 2000) in t-1.

As a final control, significant events in the 2000-2001 time period need to be addressed. The biotechnology sector is heavily dependent upon the ability to raise capital. In 2000 the sector raised a 'record breaking' $31 billion in capital and $9.4 billion through the first three quarters of 2001 (Barrett & Arnst, 2001). The terrorist events of September 11th reshaped the industry's access to capital as investors fled to safety. By the end of September 2001, the biotech sector lost 25% of its market capitalization from one year earlier (Burrill, 2001). To account for these issues, a dummy variable D200Z1 is included for the 2000 to 2001 time period.

A summary of the measures used in this study are listed in Table 4.8. The following section describes the data sources used in the analysis.

4.7 Data Collection

Three primary sources of data are used in this dissertation, the shareholders letter from a firm's Annual Report, firm patent data and firm financial data. Annual reports were collected from 1996 – 2001 utilizing three sources, the Mergent Online database, the Thomson One database and the SEC's Edgar online resource. Mergent Online is an extensive database of business and financial information on global publicly listed companies. Mergent Online is provided by Mergent, Inc. a private company. Similar to Mergent Online, the Thomson One database is an extensive collection of information on public companies. Thomson One is provided by Thomson Reuters, an NYSE listed company. The Edgar online services are a free collection document filed by public companies with the Securities and Exchange Commission. The Edgar online services are provided by the SEC.

Once collected, shareholders letters were extracted from the annual reports and converted into a machine-readable format using the ReadIris Pro 11.6 Optical Character Recognition software. All conversions by the ReadIris software were individually compared by hand against the originals for necessary corrections. Information on a firm's patent portfolio was collected utilizing the latest NBER patent data available (Hall, 2008), which included all patents through 2001. Additional information on a firm's new patent creation through 2006 was collected directly utilizing the USPTO's online patent search resources. Information from these sources were cross referenced against the RECAP database for biotech mergers/acquisition and licensing agreements to create a single picture of the core technical knowledge available to the firm at any time. RECAP is provided by Deloitte LLP and focuses on biotechnology intellectual property, alliances, clinical trial status and valuation.

Firm financial information was obtained through the use of the Compustat database. Compustat is provided by Standard & Poor's, a McGraw-Hill company. It contains information on US corporations and includes information on annual and quarterly income statements, balance sheets, statements of cash flow and supplemental information for publicly held companies.

4.8 Analytic Methodology

The longitudinal, correlational research design derived from archival data sources resulted in an unbalanced panel data set. A panel data follows a given sample of firms over a period of time and therefore provides multiple observations on each firm. Panel structures have been widely used in finance and economic research, as they possess two primary advantages over cross-sectional or time series methodologies (Hsiao, 2003). First, panel structures often provide a larger data set against the same firms, improving the robustness of the statistics. Second, panel structures enable researchers to test models they would not be able to examine using cross sectional or time series data (Hsiao, 2003). However, panel structures are not without their limitations. Panel data can suffer from heterogeneity bias and selectivity bias (Hsiao, 2003). Heterogeneity bias refers to the effect of unobserved relationships that exist between cross sectional or time series units (Hsiao, 2003). To deal with the potential for heterogeneity bias, this study uses a single industry setting and controls for significant environmental events with year controls. Selectivity bias can occur when the sample is not randomly drawn from the population (Hsiao, 2003). To address selectivity bias, the sample is constructed to capture the entire population of biotechnology IPOs that occurred during 1995 – 1996 as opposed to a sample of those firms.

Despite the limitations of panel data, this study is well suited to use a longitudinal, correlation design. The study's dependent variable 'exploratory innovation' logically occurs later in time than the independent variables. Therefore, it would be necessary to use a longitudinal as opposed to a cross sectional design to examine the relationships of interest. The implementation of a panel structure provides more observations enhancing the degrees of freedom and improving statistical power of the analysis (Hsiao, 2003).

5. ANALYSIS AND RESULTS

5.1 Overview

The model hypothesizes that the structure of a firm's core technical knowledge influences the breadth of managerial attention and that the breadth of managerial attention mediates the relationship between a firm's core technical knowledge structure and exploratory innovation. Following Ahuja and Katila (2004) and in line with Baron and Kenney (1986) and Kenney (2008), this model is tested in stages. The first stage addresses the effect of a firm's core technical knowledge structure on the breadth of managerial attention. The second stage examines separately the relationship of the breadth of managerial attention and core technical knowledge structure on exploratory innovation. Finally, the third stage examines the mediation of the breath of managerial attention on the relationship between firm core technical knowledge structure and exploratory innovation outcomes. The following briefly describes the data.

5.2 Descriptive Statistics and Correlation Matrix

Table 5.1 presents descriptive statistics for the measures. The average biotechnology firm in the sample held 56 patents, which ranged from 1 to 735. Logically, these portfolios were more concentrated at the primary classification level than the primary sub-classification level. On average these firms had PC Concentrations of 0.45 with 6.8 unique Primary Classifications while their PS

Concentration averaged 0.15 across an average of 25.4 unique primary sub-classifications.

While these firms innovated during the observation period, they were 7.6 times more likely to create new patent subclasses than new patent classes, indicating exploration that is more technically local. On average, 0.23 new Primary Class patents were created which ranged from 0 to a maximum of 4 by a single firm in a single year. Meanwhile, 1.75 new Primary Subclasses were created which ranged from 0 to a maximum of 27 by a single firm in a single year.

Regarding the attention measures, Lexical Commonality and Lexical Density are indications of the intensity with which management teams share patterns of attention. Lexical Commonality accounts for the frequency with which shareholder letters utilize the same words indicating an intensity of concept occurrence. Lexical Density accounts for the occurrence of the same concepts but does not address concept intensity. Both of these measures are not reported on a relative bases ie they are not divided by the number of words in a shareholders letter, therefore their mean statistics do not easily lend themselves to interpretation. However, it is instructive to examine their dispersion. The maximum Lexical Commonality statistic measures 751 which is 13 times greater than the minimum statistic of 55. This indicates a great deal of difference in managerial attention with the minimum statistic firm being more concentrated in its attention and not sharing a great deal of the attention characteristics of a maximal statistic firm. The difference between the maximum and minimum of the Lexical Density statistic is lower at 4.5 times but holds a similar interpretation.

The pair wise correlation matrix is presented in Table 5.2, which is a pooling of the panel data across time. Due to this pooling, the pair wise correlations are impacted by having observations derived from the same company during different time periods. To address this, Table 5.2 (1997) through 5.2 (2001) include the pair wise correlations for the individual years, 1997 – 2001. Reviewing the pooled matrix it can be seen that the dependent variable 'NoNwPS' (column 1), representing the number of new primary subclasses, is correlated with the attention variables as well as the resource structure variables. However, the dependent variable 'BNwPC' (column 2), representing the number of new primary classes, less strongly correlated with only two of resource structure variables. Review of the single year correlation tables finds a similar pattern of relationships.

Reviewing the correlation of the independent measures, the breadth of attention variables (columns 3 and 4) are closely related to each other with a pair wise correlation of .93 and show significant relationship to the measures of core technical knowledge concentration (rows 5-8) but not the ease of recombination (row 9). The resource structure variables break out between the ease of recombination measure (row 9) and the concentration measures (rows 5-8). The ease of recombination measure is not significantly correlated with the concentration measures confirming that these are separate constructs. Within the concentration measures the number of unique primary classes (column5) and the number of unique primary subclasses (row 6) are strongly correlated with a pair wise correlation of .89. This is logical as these measures are both derived from the USPTO classification system and are not impacted by intensity of firm patenting activity within a classification. By definition, an increase in unique primary classes is accompanied by an increase in the number of unique primary subclasses. The remaining resource concentration measures, Primary Class Concentration (Row 7) and Primary Subclass Concentration (Row 8), are influenced by the number of total patents within a classification. These pair wise correlations remain highly significant but decline somewhat. This logical as firm heterogeneity in patenting intensity will affect core technical knowledge concentration. As a group, the concentration measures are strongly significantly related and separate from the ease of recombination measure.

5.3 Core Technical Knowledge on Managerial Attention

Hypothesis 1 and 2 predicted relationships between the firm's core technical knowledge structure and the Breadth of Managerial Attention. Hypothesis 1 predicts that concentration in core technical knowledge structure is negatively related to the Breadth of Managerial Attention. Hypothesis 2 predicts that the Ease of Recombination of the core technical knowledge structure is positively related to the Breadth of Managerial Attention. To test these proposed relationships, I specified the following regression model, and estimated it against the two breadth of attention measures:

Attention Measure = $\alpha_0 + \alpha_1$*Number of Unique PC* (*# Unique PC*) + α_2*Number of Unique PS* (*# Unique PS*) +α_3*Concentration PC* (*PCConc*)+ α_4*Concentration PS* (*PSConc*)+ α_5*Ease of Recombination* (*Ease Recomb.*) + *controls* + *errors*

The models were tested using the linear panel 'xtreg' methods implemented in STATA. All models were examined using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). The results of this model are summarized in Tables 5.3 and 5.3 (1).

Hypothesis 1: Lexical Commonality and Lexical Density

The dependent variables, Lexical Commonality and Lexical Density, increase as managerial attention becomes broader. Hypothesis 1 predicts that concentration in a firm's core technical knowledge structure would be negatively related to the breadth of managerial attention. Model 1 on Table 5.3 examines the impact of the core technical knowledge structure variables on Lexical Commonality and Lexical Density. The model finds that core technical knowledge structure impacts the Breadth of Managerial Attention.

The Number of Unique Primary Classes is significant (p=.07) on Lexical Commonality (5.3 model 1) but not on Lexical Density (5.3 model 2). A unit increase in the number of Unique Primary Classes appears to decrease Lexical Commonality by 18.7. This is a relatively minor impact for a variable with a mean of 268 and a standard deviation of 119. The hypothesis predicts that an increase in the Number of Unique Primary Classes would increase the breadth of managerial attention; therefore, the negative effect while significant, does not support the direction of the hypothesis. The Number of Unique Primary Subclasses is significant (p=.01) on Lexical Commonality (5.3 Model 1) and also significant (p.05) on Lexical Density. The unit effects on Lexical Commonality and Lexical Density were small at 4.7 and .72, respectively. However, the sign on the coefficients are positive, supporting the direction of the hypothesis.

Primary Subclass Concentration is significant (p=.02) on Lexical Commonality (5.3 model 1) and also significant (p=.02) on Lexical Density (5.3 model 2). The hypothesis predicts that an increase in Primary Subclass Concentration would decrease the Breadth of Managerial Attention, but this is not what the results find. The positive sign on Primary Subclass Concentration does not support the hypothesis. The regressions indicate that a 1% increase in concentration at the Primary Subclass level increases Lexical Commonality by 478 units and Lexical Density by 98 units. These effects are larger than the effects that were found related to the number of unique primary subclasses.

I found it unusual that the regression would find an effect for the number of Unique Primary Classes but no effect with respect to the Primary Class Concentration. To examine this further, I lagged the attention dependent variables by one year. In the lagged regression, Table 5.3(1) models 1 and 2, Primary Class Concentration is significant (p=.001) on Lexical Commonality and (p=.02) Lexical

Density. The negative sign on the coefficients indicate that increases in Primary Class Concentration reduce the Breadth of Managerial Attention as proposed by hypothesis 1. The signs on the other significant variables are the same as shown on the concurrent model discussed above. The results of the regressions with respect to hypothesis 1 are summarized in Table 5.7.

Hypothesis 2: Ease of Recombination

Hypothesis 2 predicts that the Ease of Recombination in a firm's core technical knowledge structure would be positively related to the Breadth of Managerial Attention. Under this hypothesis, as the Ease of Recombination measure increases, I would expect to find Lexical Commonality and Lexical Density increasing as well. The analysis finds the Ease of Recombination significant with respect to both Lexical Commonality (5.3 model 1; p=.05) and the Lexical Density (5.3 model 2; p=.02). In both models, the Ease of Recombination coefficient is positive, supporting the direction of the hypothesis. A one unit increase in the Ease of Recombination positively affects a 602-unit increase in Lexical Commonality and a 144 unit increase in Lexical Density. These effects are substantial given the mean and variance of the Lexical Commonality and Lexical Density measures.

Hypothesis 1 and 2 Results Summary

Hypothesis 1 and 2 were examined by conducting linear panel regressions with Lexical Commonality and Lexical Density as dependent measures of the breadth of managerial attention. The independent variables addressed concentration and ease of recombination as structural measures of a firm's core technical knowledge portfolio. Hypothesis 1 predicted that Concentration in a firm's core technical knowledge portfolio would be negatively related to the Breadth of Managerial Attention. Mixed results were found. The number of unique primary subclasses and the primary subclass concentration were both significant on the two measures of the breadth of managerial attention. However, the sign of the coefficient on the number of unique primary subclasses supported the hypothesis while the sign on the coefficient on the primary subclass concentration did not support the hypothesis. Hypothesis 2 predicted that the Ease of Recombination of the firm's core technical knowledge portfolio would be positively related to the breadth of managerial attention. Uniform support was found for the influence of the Ease of Recombination on the measures of the Breadth of Managerial Attention. These results are summarized in Table 5.7.

Four of the five measures of structure in a firm's core technical knowledge were found significantly related to the breadth of managerial attention. However, the size of the effect varied. Primary Subclass Concentration and Ease of Recombination were found to have the most substantial effects while the effects of the Number of Unique PC and the Number of Unique PS were statistically significant but less substantial.

Correlation for Mediation Analysis

According to Baron and Kenney (1986) mediation is examined in three regression stages. First, the dependent variables are regressed on the independent variables, supporting a direct effect. Second, the mediator is regressed on the independent variables establishing a correlation between the independent variable and the mediator. Third, the dependent variable is regressed on the independent variables and the mediator with the coefficients examined against the first stage.

Hypothesis 1 and 2, examined above, addressed the link between the core technical knowledge structure (the independent variable) and the breadth of managerial attention (the mediator). Thus, hypothesis 1 and 2 parallel Baron and Kenney's (1986) second step. However, due to limitations on the ability to collect a full complement of shareholders letters, the data used to establish correlation in the mediation analysis is eighteen observations less than what was used to examine hypothesis 1 and 2. Table 5.3 (2) re-examines the link between core technical knowledge structure and the breadth of managerial attention but restricts the number of observations to those that can be used in the meditation analysis.

The results in Table 5.3(2), on the reduced sample, demonstrate a correlation between structure in a firm's core technical knowledge and the breadth of managerial attention supporting the second regression stage in Baron and Kenney's (1986) stepped mediation analysis. Examination of the significant coefficients on the reduced sample find the effect of the number of unique primary classes, the number of unique primary subclasses and primary class concentration similar to that observed in Tables 5.3 and 5.3(1). Dissimilar to the results observed in the larger sample, the significance associated with Primary Subclass Concentration and Ease of Recombination are not observed in the reduced sample.

5.4 Core Technical Knowledge Structure On Innovation

As noted above, mediation is examined in three regression stages (Baron and Kenney, 1986). First, the dependent variables are regressed on the independent variables, supporting a direct effect. Second, the mediator is regressed on the independent variables. Third, the dependent variables are regressed on the independent variables and the mediator. This section addresses the first step recommended by Baron and Kenney (1986) and examines the direct effect of core technical knowledge structure on exploratory innovation outcomes.

The model proposes that the breadth of managerial attention fully mediates the relationship between a firm's core technical knowledge structure and exploratory innovation outcomes. As a fully mediated model, I do not develop specific hypothesis about the direct relationship between a firm's core technical knowledge structure and exploratory innovation outcomes. However, such a relationship is implied and is necessary to test under the Baron and Kenney conditions.

The research model uses two dependent variables that represent different levels of exploratory innovation. First the creation of a new primary class and second the creation of new primary subclasses. These two dependent variables are examined separately in the following two sections.

5.4.1 The Creation of New Primary Classes

The creation of new primary classes appears to be relatively rare. The sample included all 1995 and 1996 biotechnology IPOs that created a new patent during the observation period, from 1996 – 2006. Of the possible 400 firm year observations (40 companies for 10 years), 294 were able to be collected (106 observations were unavailable due to mergers/ acquisitions and liquidations). Of the 294 firm year observations collected across 40 firms, no new primary classes were created during 245 periods, while one new primary class was introduced in 36 firm/years. Of the remaining 14 firm/years, most introduced only two new primary classes in a period. See Table 5.4 for this distribution.

The creation of new patents is traditionally modeled using a negative binomial distribution (Hausman, Hall, & Griliches, 1984). However, the extremely high zero count (83.3%) in this data makes the use of this distribution a poor fit. Given the relative infrequency with which new patent classes in any firm/year are introduced, in excess of 1, it appears that this process is best modeled as binary. By converting the count data to binary information, there is a slight loss of resolution. Thirteen observations in the count data, which represent 4.4% of the observations, are converted from count to binary. A comparison of the converted binary and the original count distribution for the Number of New Primary Classes is shown in Table 5.4.

By converting the number of new primary classes created in a firm/year to a binary variable, indicating if a new primary class was created in a firm/year (Binary New Primary Class - BNwPC), the distribution can be modeled using a panel logit structure.

To examine the relationship between a firm's core technical knowledge structure and the creation of a New Primary Class (BNwPC), I specified the following regression model:

BNwPC = α_0 + α_1*Number of Unique PC (No. Unique PC)* + α_2*Number of Unique PS (No. Unique PS)* +α_3 *Concentration PC (PC Conc.)*+ α_4*Concentration PS (PS Conc.)*+ α_5*Ease of Recombination (Ease Recomb.) + controls + errors*

The following analysis was conducted using the STATA software and the 'xtlogit' commands for logit panel data analysis. The model is tested using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). In a separate analysis, the lagged effect of the core technical knowledge structure on BNwPC is analyzed. A one year lag was identified as the most appropriate and is utilized here. The results of this model are summarized in Table 5.5 model 0 and model 1. The results in Table 5.5 Model 0 show the pooled calculation on the 290 observations discussed above. Model 1 is a restricted model to ensure that this step of the analysis is run on the same observations as the final step of the mediation analysis.

The overall logit regression model was significant, (p=.0002) with the independent variables; Number of Unique Primary Classes significant (p=.01). The significance of this variable supports the relationship of structure in a firm's core technical knowledge resources with a firm's exploratory innovation outcomes. However, since shareholders letters were unable to be collected for every firm in every year, the number of observations has to be adjusted so that this step of the mediation model is estimated on the same observations as the final step of the mediation analysis. Adjusting in this way, model 1 on Table 5.5 shows the results of the regression analysis run on the 157 observations where shareholders letters were available. In this reduced sample, no evidence is found which links a firm's core technical knowledge structure to the creation of new Primary Classes.

Since this is a fully mediated model, I do not develop specific hypothesis about the direct relationship between a firm's core technical knowledge structure and exploratory innovation outcomes. However, the full model does imply a direction of the relationship. Without the meditational influence of managerial attention, the model implies that increasing concentration in a firm's technical knowledge structure would negatively influence exploratory innovation. In Table 5.5 model 0, the sign on the Number of Unique PC is positive, supporting the direction implied by the model. As the number of Unique Primary Classes increases, the portfolio becomes more diverse which the model indicates is positively related to exploratory innovation outcomes. Table 5.5 reports the incident rate ratios (IRR) of the logistic regression. The IRR on the Number of Unique PC is 1.23. Interpreting this, I would expect to see about a 23% increase in the odds of creating a new primary class as the firm adds an additional primary class to the core technical knowledge portfolio.

5.4.2 The Impact of Core Knowledge Structure on New Primary Subclasses

To examine the relationship between a firm's core technical knowledge structure and exploratory innovation as measured by the number of New Primary Subclasses created (NoNwPS), I specified the following regression model:

NoNwPS = $\alpha_0 + \alpha_1$Number *of Unique PC (No. Unique PC)* + α_2*Number of Unique PS (No. Unique PS)* +α_3 *Concentration PC (PC Conc.)*+ α_4*Concentration PS (PS Conc)*+ α_5*Ease of Recombination (Ease Recomb.) + controls + errors*

The following analysis was conducted using the STATA software and the 'xtnbreg' commands designed for negative binomial panel data analysis. This model is tested using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). The results of this analysis are summarized in Table 5.6 model 0 and model 1.

The overall negative binomial panel regression model was significant, Table 5.6 model 0 (p=.000) with the following significant independent variables; Number of Unique Primary Classes (p=.000), Number of Unique Primary Subclasses (p=.000), PS Concentration (p=.06) and Ease of Recombination (p=.01). Similar to the above discussion on the creation of New Primary Classes, the significance of these variables supports a relationship between the structure in a firm's core technical knowledge resources and a firm's exploratory innovation outcomes, in this case, the number of new patent subclasses created. Since this is a fully mediated model, I do not develop specific hypothesis about the direct relationship between a firm's core technical knowledge structure and exploratory innovation outcomes. However, the model does imply a direction of this relationship. Without the meditational influence of managerial attention, the model implies that increasing concentration in a firm's technical knowledge structure would negatively influence exploratory innovation outcomes while increasing ease of recombination would positively influence exploratory innovation outcomes. In Table 5.6 model 0, the panel negative binomial model examining the number of new primary subclasses created, the IRR for the Number of Unique Primary Classes is greater than one while the IRR on the Number of Unique Primary Subclasses, Primary Subclass Concentration and Ease of Recombination is less than one. As discussed above, the model does not develop specific hypothesis about the direct relationship between a firm's core technical knowledge structure and exploratory innovation outcomes. However, the full model does imply a direction of the relationship. The relationships found in the regression analysis (Table 5.6 model 1), present mixed results for the directions hypothesized in the model. These results suggest that adding new primary classes improves the probability of creating new patent subclasses while adding new primary subclasses decreases the probability of creating new primary subclasses.

In order to conduct all steps of the mediation analysis on the same observations, Table 5.6 model 1 restricts the regression analysis to those observations where shareholders letters were able to be collected. Similar to Table 5.6 model 0, Table 5.6 model 1 finds a relationship between the firms' resource structure and the creation of new patent subclasses. Similar to model 0, the Number of Unique PC and the Number of Unique PS are significant and have very similar results. However, in this reduced model, PS Concentration and Ease of

Recombination become insignificant whereas PC Concentration becomes significant at p=.06. In the mediation analysis, I concentrate on those coefficients significant in both Table 5.6 model 0 and model 1, the number of unique primary classes and the number of unique primary subclasses. The first step in the Baron and Kenny (1986) and Kenny (2008) stepped regression analysis of mediation is to establish a direct relationship. This analysis as summarized in Table 5.6 models 0 and 1 establish this direct link between the structure in a firm's core technical knowledge and its innovative outcomes.

5.5 Managerial Attention on Innovation

Hypothesis 3 predicts a positive relationship between the Breadth of Managerial Attention and the firm's exploratory innovation outcomes. These outcomes are measured by a firm's creation of a new patent with either a new to the firm primary class or new to the firm primary sub class. These two dependent variables are discussed separately.

5.5.1 The Impact of Core Knowledge Structure on New Primary Classes

To examine the effect of the breadth of managerial attention on the occurrence of new primary classifications (BNwPC), I specified the following regression model.

$$BNwPC = \alpha_0 + \alpha_1 \text{Lexical Commonality (Commonality)} + \alpha_2 \text{Lexical Density (Density)} + \text{controls} + \text{errors}$$

This model was analyzed using the STATA software and the 'xtlogit' commands designed for logit panel data analysis. The model is tested using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). In a separate analysis, the lagged effect of the attention variables on BNwPC is analyzed. A 2 year lag was identified as the most appropriate and is utilized here. The results of this model are summarized in Table 5.5 model 2. Neither of the Breadth of Attention measures are significant in the model. Hypothesis 3 predicts a positive relationship between the Breadth of Managerial Attention and the firm's exploratory innovation outcomes. The results of this analysis do not provide support for this hypothesis as summarized in Table 5.7.

5.5.2 The Creation of New Primary Subclasses

Hypothesis 3 predicts a positive relationship between the Breadth of Managerial Attention and the firm's exploratory innovation outcomes. To examine the relationship of the breadth of managerial attention on the creation of new primary subclasses (NoNwPS), I specified the following regression model.

$$NoNwPS = \alpha_0 + \alpha_1 Lexical\ Commonality\ (Commonality) + \alpha_2 Lexial\ Density\ (Density) + controls + errors$$

This model was analyzed using the STATA software and the 'xtnbreg' commands designed for negative binomial panel data analysis. The model is tested using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). In a separate analysis, the lagged effect of the attention variables on NoNwPS is analyzed. A two year model was identified as the most appropriate and is utilized here. The results of this model are summarized in Table 5.6 model 2.

Both of the Breadth of Attention measures, Lexical Commonality (p=.003) and Lexical Density (p=.002) are significant in the model (Table 5.6 model 2). The significance of the coefficients confirms a relationship between managerial attention and the firm's creation of new to the firm primary sub classes. Hypothesis 3 predicts a positive relationship between the Breadth of Managerial Attention and the firm's exploratory innovation outcomes. The IRR of the variables present mixed results for this hypothesis. Lexical Commonality is significant (p=.003) but the IRR is .99 indicating that as the Breadth of Managerial attention increases by a unit, the rate of creation of New Primary Subclasses is reduced by 1%. Lexical Density is also significant (p=.002) with an IRR of 1.03 which indicates that as the Breadth of Managerial attention increases, the rate of creation of New Primary Subclasses is enhanced. I would expect a unit increase in Lexical Density to increase the rate of New Primary Subclass creation by 3%. Overall, this analysis finds support for a relationship between the Breadth of Managerial Attention and the firm's creation of New Patent Subclasses. However, the effect of the individual coefficients for the Breadth of Managerial Attention (Table 5.6 model 2) are varied and do not present a uniform effect on the creation of New Patent Subclasses. Interestingly, the IRR supporting the hypothesis has a stronger effect (1.03) than the coefficient that does not support the hypothesis (.99).

The high correlation between Lexical Commonality and Lexical Density present the potential for multicollinearity to influence the results. However, due to the non-linear nature of the regression model, linear tests of multicollinearity, such as the variance inflation factor are not applicable (cameron & trivedi, 1998). For nonlinear count models, the Hausman test is normally applied to determine whether a fixed or random effect specification is appropriate (cameron & trivedi, 1998). The Hausman test indicated that a random specification was appropriate throughout the regression that make up Table 5.6. In general, a common symptom of multicollinearity is a highly significant regression model with non significant coefficients. This common symptom is not present in Table 5.6 model 2. The relative results between Lexical Commonality and Lexical Density are discussed more fully in the Discussion section.

5.6 Meditational Influence of Managerial attention

As noted above, according to Baron and Kenney (1986) mediation is examined in three regression stages. In the first stage, the dependent variables are regressed on the independent variables, establishing a direct effect. This analysis, was conducted within section 5.4 and found support for the relationship between core technical knowledge structure and exploratory innovation outcomes for both innovation measures when the models were not restricted to those observations where shareholders letters were available, see Table 5.6 model 0 and Table 5.5 model 0. However, when the number of observations were limited so that the steps of the meditation analysis were conduced on the same observations, significance was only found between the resource structure variables and the creation of New Patent Subclasses, see Table 5.6 model 1 and Table 5.5. Model 1.

In the second stage of the mediation analysis, the mediator is regressed on the independent variables. This analysis was conducted in section 5.3 which found support for a relationship between structure in a firm's core technical knowledge and managerial attention.

The third regression stage of the mediation analysis is to examine the dependent variables on the mediator and the independent variables (Baron & Kenny, 1986; Kenny, 2008). This following section addresses this third regression stage. However, due to the lack of direct effect on the creation of new primary classes, this section only examines mediation with respect to the creation of new primary subclasses. Since a direct effect was not established in section 5.4.1 with respect to the creation of new primary classes, mediation is not possible and therefore the analysis is not included.

5.6.1 Mediation: The Creation of New Primary Subclasses

Hypothesis 4 predicts that the breadth of managerial attention fully mediates the relationship between structure in a firm's core technical knowledge and firm exploratory innovation outcomes. To examine this relationship, with respect to the firm's creation of new primary subclasses, I specified the following regression model, following the 3rd regression step (Baron & Kenny, 1986; Kenny, 2008). This model examines the effect the core technical knowledge structure on exploratory innovation outcomes while controlling for the breadth of managerial attention.

NoNwPS = α_0 + α_1*Number of Unique PC (No. Unique PC)* + α_2*Number of Unique PS (No. Unique PS)*+α_3 *PC Concentration (PCConc)* + α_4 *PS Concentration (PSConc)* + α_5*Ease of Recombination (Ease Recomb)*+ α_6*Lexical Commonality (Commonality)* + α_7*Lexical Density (Density) + controls + errors*

This model was analyzed using the STATA software and the 'xtnbreg' commands designed for negative binomial panel data analysis. The model is tested using a 'fixed effect' specification as well as a 'random effect' specification. The Hausman test was used to assess the appropriateness of the fixed or random specification (Hsiao, 2003). The results of this model are summarized in Table 5.6 model 3.

The fully specified model is significant (p= .004) with both Core Technical Knowledge Structure and Breadth of Attention variables significant. The significance of the Breadth of Attention measures supports the 3rd regression stage of the mediation analysis, establishing an effect of the mediator on the dependent variable controlling for the initial variable. The final step of the mediation analysis is a comparison of the direct effect coefficients (step 1) to the fully specified coefficients (step 3).

Given the significance of the Core Technical Knowledge Structure variables, the model does not support the full mediation of Hypothesis 4. However, to examine the potential for partial mediation, I compared the IRR values for the knowledge structure variables in Table 5.6 model 1 against the IRR values in model 3. However, I have concentrated on those variables that are also supported in the full model, Table 5.6 model 0. In Table 5.6 model 1, the Number of Unique Primary Classes has an IRR value of 1.17. This decreases to 1.14 in model 3, indicating a level of partial mediation. In model 1, the Number of Unique Primary Subclasses has an IRR value of .98. This does not change in model 3.

5.7 Summary

The analysis found mixed support for the overall model as summarized in Table 5.7. Hypothesis 1 proposed that concentration in a firm's core technical knowledge would decrease the breadth of managerial attention. Supporting the hypothesis, Primary Class Concentration and the Number of Unique Primary subclasses were significant on the measures of attention with the sign of the coefficients supporting the direction of the hypothesis. Other significant relationships were identified but the signs of the coefficients did not support hypothesis one. Primary Subclass Concentration was significant on both attention measures but sign of the coefficient did not support the hypothesis one. Also, the number of unique primary classes was significant on one of the attention measures but the sign of the coefficient did not support hypothesis one. Regarding Hypothesis one, there were eight potential relationships between the resource structure and attention measures with the models founding seven significant coefficients. Four of these significant relationships supported the direction of hypothesis one and three did not. These results are summarized in Table 5.7. The mixed support of the hypothesis are discussed in greater depth in the Discussion section.

Hypothesis 2 proposed that the Ease of Recombination in the firm's core technical knowledge portfolio would positively impact the Breadth of Managerial Attention. This hypothesis was supported across both of the breadth of managerial attention variables. Thus, the models found support for hypothesis 2, as summarized in Table 5.7.

Hypothesis 3 proposed that the breadth of managerial attention positively impacted a firm's exploratory innovation outcomes. The analysis did not find an effect for the breadth of managerial attention on the creation of new patent classes but did find an effect on the creation of new patent subclasses. Within this effect, mixed support was found for hypothesis 3. Lexical Density supported the direction of the hypothesis while Lexical Commonality was significant but did not support the direction of the hypothesis, as summarized in Table 5.7. The mixed support of the hypothesis are discussed in greater depth in the Discussion section.

Hypothesis 4 proposed that managerial attention fully mediates the relationship between structure in a firm's core technical knowledge and exploratory innovation outcomes. A direct effect of core technical knowledge structure on the creation of new primary classes was identified when the number of observations was not restricted (Table 5.5 model 0). However, a similar direct effect was not found when the number of observations was restricted, due to the need to run the steps of the mediation analysis on the same variables and the inability to collect all shareholders letters (Table 5.5 model 1). Due to the lack of a direct effect, the mediation analysis was not conducted with the creation of new primary classes as a dependent variable. With respect to the creation of new primary subclasses, a direct effect was identified and the analysis found evidence that the breadth of managerial attention did partially mediate the relationship between a firm's core resources structure and the creation of new primary subclasses.

6. DISCUSSION

I investigated the impacts of core resource structure and the breadth of managerial attention exploratory innovations. In the following, I evaluate the findings of the study in relationship to existing theory and identify theoretical contributions as well as potential research opportunities. The limitations of this research are discussed in section 7.0.

Technical innovation is a central concept to economic growth, which has traditionally been viewed as function of the structure of a firm's core technical knowledge and exploratory search, a cognitive process. Attention as the first step in the cognitive processing model should serve a central function in management's identification of innovative opportunities. However, the role of managerial attention to firm level innovation has received minimal examination with respect to technological adoption and none with respect to exploratory innovation. Further, the antecedents of managerial attention itself are understudied with no research identified that examined the role a firm's core resource structure on managerial attention.

I first explored the impact of resource structure on managerial attention by examining the effect of Concentration and Ease of Recombination, as measures of a firm's Core technical knowledge, on the Breadth of Managerial Attention. Second, this dissertation examined the effect of the Breadth of Managerial Attention on exploratory innovation and third, this dissertation examined the relationship of managerial attention and resource structure on exploratory innovation by studying the Breadth of Managerial Attention as a mediator between firm core technical knowledge structure and exploratory innovation outcomes. Table 5.7 presents an overall summary of the study's results, which discussed in the following.

6.1 Core Knowledge Structure and the Breadth of Managerial Attention

In the first part of the analysis, hypothesis 1 and 2, examined the relationship between a firm's core technical knowledge structure and the breadth of managerial attention. Mixed results were found with respect to hypothesis one while uniform support was found for hypothesis two. Hypothesis one, predicted a negative relationship between concentration in the firm's core technical knowledge and the breadth of managerial attention, i.e. as the portfolio is more concentrated, managerial attention was expected to narrow. Analysis of the results found seven significant relationships out of eight possible relationships, Table 5.7. Four of these supported the direction of the hypothesis while three did not. Uniform support was found for H2 while mixed support was found for H1. First, I will discuss the significant coefficients that do not support hypothesis one and then I will come back to the overall significance of the hypothesis 1 and 2 findings.

Finding significant relationships that did not support hypothesis one is surprising as the absorptive capacity literature argues that firms with a broader knowledge base are more able to acquire and assimilate new knowledge. The significant relationships that do not support hypothesis one infer that as a firm's core technical knowledge portfolio is more concentrated, the breadth of managerial attention widens. These 'reversed' relationships are concentrated in two variables, Primary Subclass Concentration and the Number of Unique Primary Classes. The question becomes, what theoretical justification would there be for these variables to move in opposition to hypothesis one?

Mixed Results: Primary Subclass Concentration

Primary Subclass Concentration was significant in the H1 regression but the sign was reversed from what was expected. I believe this unusual finding can be explained by examining the slack search (Greve, 2003; March & Simon, 1958a) and aspiration level search (Cyert & March, 1963) literature. As a firm has increased Primary Subclass Concentration they have greater absorptive capacity within that area of technical knowledge (Cohen & Levinthal, 1990; Zahra & George, 2002). This means that the firm is more able to acquire, assimilate, transform and exploit new knowledge (Zahra & George, 2002). At the same time, the firm is moving up the learning curve related to that area of knowledge concentration. Learning curve research has explained that as a firm moves along the learning curve, the incremental changes in knowledge needing to be absorbed become smaller and more incremental (Boh, Slaughter, & Espinosa, 2007). Based upon this logic, as a firm has a greater concentration in a specific knowledge area it is more able to absorb external information, within that area of concentration, that information is at the same time incrementally less differentiated from what the firm has previously absorbed. Under these conditions, the firm is developing slack capacity to absorb external information, which are the characteristics that can lead to slack search (Greve, 2003; March & Simon, 1958a) thus broadening managerial attention. It is possible that, in the current research setting, that Primary Subclass Concentration leads to a broadening of managerial attention due to the effect knowledge concentration may have on slack search.

A second possibility for why Primary Subclass Concentration leads to broader managerial attention outcomes can be found in the aspiration level search literature (Cyert & March, 1963; Greve, 1998; Winter, 2000). Aspiration level search occurs when organizational attention is drawn to a situation due to the failure of the firm to achieve an expected level of performance. As a firm increases its level of Primary Subclass Concentration, it inherently is more tied to the performance of a specific set of knowledge. Research has demonstrated that technologies progress along an 'S' shaped technology trajectory (Dosi, 1982), where the technology initially increases in performance at an increasing rate as scientists and others increase their understanding of the nature of the technology and how to improve it. After this point, the technology may continue to increase in performance but at a decreasing rate of improvement. For a firm closely tied to a specific technology, such an inflection point may act as an aspiration level failure that triggers exploratory search. This logic would argue that a firm with a high Primary Subclass Concentration is more likely to respond to decreased rates of improvement in its portfolio technology with exploratory search, which is what was observed in the analysis.

Mixed Results: Number of Unique Primary Classes

The Number of Unique Primary Classes was significant in the H1 regression but the sign was reversed from what was expected. Further, the Number of Unique Primary Classes and the Number of Unique Primary Subclasses were both significant on the Breadth of Managerial Attention measures with the Number of Unique Primary Subclasses supporting H1 and the Number of Unique Primary Classes not supporting H1. The question becomes why would the number of unique categories at these two levels have differential effects on the Breadth of Managerial Attention. I think an explanation can be found in the recombinant innovation literature (Fleming, 2001; Fleming & Sorenson, 2001) as it relates to the different level of the measures. The basis of the recombinant innovation literature is that inventors require a portfolio of unique elements to recombine in the innovation process. Below this level, innovation suffers due to a lack of recombinant elements. Above this level, innovation suffers due to the cognitive demands of dealing with too many possible recombinant elements. When measured at the Primary Class level, each primary class represents a new area of knowledge which inherently contains a sizable number of individual Primary Subclass knowledge pieces. Thus, the addition of a new Primary Class radically increases the recombinant possibilities for the firm. For management to take advantage of this radical increase in recombinant possibilities, managerial attention must focus on understanding and taking advantage of these possibilities. Thus, the addition of a new primary class could have the effect of focusing managerial attention as opposed to the hypothesized effect of broadening managerial attention. In contrast to the Primary Class level, the addition of a new Primary Subclass represents a very incremental increase in the recombinant possibilities of the core technical knowledge portfolio. Such a change would not require managerial attention to focus inward in order to understand the recombinant possibilities as the addition is already within the overarching knowledge of the firm.

Relationship of Resource Structure to Managerial Attention

Two of the central themes in strategy research are a resource based and a cognitive perspective. However, these streams of research largely do not overlap. Ocasio (1997) set forth an attention based view of the firm and proposed a firm's resources as an important influence on the way the firm structures managerial attention. Ocasio's (1997) laid a logical bridge between the cognitive and resource based perspective but the construction of the bridge has not been further developed. Core resource structure is fundamental to the resource based view. I have sought to extend Ocasio's attention based view of the firm by arguing that core resource structure is a central bridging mechanism between these perspectives. Hypothesis 1 and 2 addressed this by posing the research question, 'What is the influence of a firm's core technical knowledge structure on managerial attention?' The results found nine of ten potential relationships statistically significant, providing evidence of a link between resource structure and managerial attention.

The results for Hypothesis 1 were mixed with four of seven significant coefficients supporting the hypothesis. The three significant coefficients that did not support the hypothesis are discussed above. The results for Hypothesis 2 were uniformly supported.

The significance found across both of these constructs supports the position that 'what you have affects what you pay attention to'. Finding a link between the resource based and cognitive perspectives is important but also calls for further investigation. I see this developing along two lines addressing resources as well as cognition. With respect to resources, this study was limited to an examination of core technical resources. It would be worthwhile to relax this limitation and examine the influence of other resources on managerial cognition. The measures of concentration used in this study are common to resource based scholars. However, the ease of recombination construct was taken from the recombinant innovation literature and was not previously applied at the firm level. It would be worthwhile to identify other resource structure constructs that may have a bearing on managerial cognition. With respect to cognition, this study focused on a limited aspect of cognition, the breadth of managerial attention. This is a broad measure of managerial attention. Other scholars have focused on specific events, such as the introduction of a new technology to an industry (e.g. Eggers & Kaplan, 2008; Kaplan, 2008). Both forms of attention have been found impactful on a firm's innovation activities. It would be worth while to examine the interplay between the broader internal influences (resource structure) and the more specific external influences (an environment experiencing some specific event) on managerial attention.

6.2 The Breadth of Managerial Attention and Exploratory Innovation

The second part of this dissertation, focused on the relationship between the Breadth of Managerial Attention and the firm's Exploratory Innovation outcomes. Hypothesis 3 proposed that the breadth of managerial attention is positively related to the firm's exploratory innovation outcomes. Two interesting outcomes are observable from the hypothesis 3 analysis. First, the lack of effect at the primary class level as opposed to the effect observed at the Primary Subclass level and second, the mixed effect that was observed at the primary subclass level.

There is a growing body of literature which argues that senior management attention is important to a firm's exploratory behavior. Scholars have often focused on managerial attention to specific environmental issues. For example, Eggers & Kaplan (2008) and Kaplan (2003) focused their research on managerial attention to fiber optics and found an influence on the firm's adoption of this external technology. To generalize, senior management attention to a specific environmental issue affected the firm's non local exploratory search. Unlike the above research, I examined a broader measure of managerial attention and bifurcated the dependent variable to examine the effect of attention on the localness of exploratory innovation. Using this broader measure, I found an effect on innovation that was more local (Table 5.6 vs Table 5.5) than that identified by Eggers & Kaplan (2008) and Kaplan (2003). From the differences between these studies, it would appear that the influence of managerial attention on search can operate at different levels of localness depending upon the focus of managerial attention. Attention that is focused on a specific environmental condition is more likely to move the firm's exploratory search in a more non-local way to address that environmental condition. However, senior management attention that is not focused on a specific environmental condition but is just broader in general is more likely to affect exploratory search which is more local. This influence is not trivial given the punctuated equilibrium model of environmental change (Romanelli & Tushman, 1994; Tushman & Anderson, 1986). During periods between discontinuous events, such as the fiber optic revolution, a broader pattern of managerial attention may allow a firm to adapt more effectively to the dominate environmental conditions. The differences between these studies also points out a need for a better understanding of the relationship between general patterns of managerial attention and managerial attention to specific environmental events. An open question becomes; Do generalized patterns of managerial attention, such as breadth of attention, lead to earlier identification of specific environmental shifts?

A second aspect of interest from the analysis of hypothesis 3 is the mixed results observed on the breadth of attention measures. Both Lexical Commonality and Lexical Density were significant (Table 5.6 model 2). However, the IRR of the coefficients were mixed. The IRR of Lexical Density was greater than 1 and thus supported the hypothesis while the IRR of Lexical Commonality was less than 1 and did not. While these measures were not significant on the creation of new primary classes (Table 5.5. model 2), the IRR's of the coefficients were similar. Why are Lexical Commonality and Lexical Density generating opposing IRR values? I think the difference may originate in the way the measures treat the frequency of the words occurring in the shareholders letter. Lexical Commonality factors in the frequency of word occurrence while Lexical Density addresses the binary occurrence of the concept without regard to frequency. The results indicate that breadth of attention to different categories may positively influence exploratory innovation but that even when management pays attention to a wide number of categories, concentrated attention within those categories can alter the flow of incoming information and negatively impact the level of exploratory innovation. Given the discussion and research question above on the relationship between generalized and specific patterns of attention, it would be important to further examine the breadth of attention construct for the differential effects that appear to be present due to the number of categories attended vs the intensity across those categories.

6.3 The Breadth of Managerial Attention as a Mediator

Hypothesis four examined the breadth of managerial attention as a mediator between a firm's core technical knowledge structure and its exploratory innovation outcomes. A direct effect was not identified regarding the creation of new primary classes thus mediation was not examined against this innovation measure. Hypothesis four was tested against the creation of new primary subclasses. Of the two measures of attention, the analysis found weak evidence of partial mediation with one measure (Number of Unique Primary Classes) showing a minor decrease in IRR (Table 5.6 models 1 and 2). In essence, the model indicates that core resource structure and managerial attention operate as separate paths to more local exploratory innovation. With respect to the literature addressing the importance of managerial attention, the question becomes, why doesn't the breadth of managerial attention mediate the relationship between core technical knowledge structure and exploratory innovation? I think the answer lies in the dependent variable being a more local measure of exploratory search. By definition the creation of new primary subclasses is more local than the creation of new primary classes. Being more local, the innovation is more closely tied to the firm's existing knowledge. There is a significant body of scholarly work addressing the relationship of the firm's core resources to innovation outcomes through local search. This research has often focused on processes that occur within the firm and below the level of managerial attention. Such processes include the natural occurrence of variation and retention (e.g. Barnett, Burgelmantoby, Stuart, & Podolny, 1996; Stuart & Podolny, 1996) and informational network approaches (e.g. Sorenson et al., 2006). These processes, in addition to managerial action, can drive more local innovative outcomes. The results of the mediation analysis support this type of a position. The model finds that the breadth of managerial attention contributes to the creation of new primary subclasses along with the influence of structure in the firm's core technical resources. An interesting extension of this research would be to utilize three new patent variables to measure exploratory innovation; the creation patents with 1) new primary classes 2) new primary subclasses and 3) the same primary class and primary subclass. This structure could allow a better determination of the function of the attention process in exploratory vs non exploratory innovation.

6.4 Direct Effect

While the model did not directly hypothesize a direct effect between a firm's core technical knowledge structure and exploratory innovation outcomes, the direct effect was examined as the first step in the mediation analysis (Table 5.5 models 0 & 1 and 5.6 models 0 & 1). Interestingly, the direct effect was more pronounced in the creation of new primary subclasses than in the creation of new primary classes. This finding is in line with the discussion above which points toward a larger role for managerial attention to environment specific issues on non-local search and innovation activities. Within the direct effect observed, the number of unique primary classes and number of unique primary subclasses were significant in both the limited (Table 5.6 model 1) and non-limited models (Table 5.6 model 0). With the number of unique primary classes also significant against the creation of a new primary class (Table 5.5 model 0). The underlying logic of these variables is taken from the recombinant innovation literature (Fleming, 2001) which argues that innovation is a process of recombination and that inventors need to have different knowledge elements available for recombination. This literature was developed and tested at the innovation level and has not been previously applied at the firm level. There are three interesting findings related to the significance of these variables.

First, both of the 'number of unique element' measures are significant while the Herfindahl concentration measures are not uniformly significant in the models (Table 5.6 models 0 and 1). This is interesting in that it contrasts two different views of innovation, that of core competencies and that of recombinant innovation.

The fundamental idea behind the measures of primary class and primary subclass concentration is that firms must concentrate their knowledge efforts in order to generate the absorptive capacity which allows the assimilation of new related information that can facilitate innovation (Cohen & Levinthal, 1990). The fundamental idea behind the unique element measures is that inventors need a pool of different knowledge elements available for recombination in order to innovate. It is the number of different elements available and the ability to recombine them which impacts innovation outcomes (Fleming, 2001). The recombinant innovation literature was developed at the innovation level and has not previously been examined at the firm level. The results in Table 5.6 models 0 and 1 indicate that the number of unique elements available to the firm has a more uniform effect on the firm's exploratory innovation outcomes than concentration in the core technical knowledge portfolio does. From a general perspective, this supports the recombinant innovation literature more than it does the core competency literature. However, the core competency literature has a longer history of scholarly study. The contrasting perspectives these two literatures provide and the results of this study calls for further investigation into the comparative performance of these two perspectives.

The second interesting finding related to the significance of the 'number of unique element' measures (Table 5.6 model 0 and 1), is the positive effect seen from the primary class level and the negative effect seen from the primary subclass level. This indicates that it is not just the number of elements available for recombination that leads to innovation but also the relationship of the new element to the existing portfolio. In this study, the IRR on the number of unique primary classes is 1.17 indicating that the addition of a primary class is expected to increase the creation of new primary subclass by 17%. Meanwhile, the IRR on the number of unique primary subclasses is .98 indicating that the addition of a new primary subclass is expected to decrease the creation of a new primary subclass by 2%. It is the addition of the more distant new class which has a greater effect on the firm's innovative activities. This adds to the recombinant innovation literature which does not address the incremental effect on innovation performance of new knowledge relative distance.

The third interesting finding related to direct effect examination, is the lack of significance for the ease of recombination. Within the recombinant innovation literature, the ease with which a unique knowledge element could be recombined with other knowledge elements had a more profound impact than the number of unique elements. The ease of recombination is significant in Table 5.6 model 0 but not in the restricted model 1, while the number of unique element measures are applicable across these models. The insignificance of the ease of recombination in Table 5.6 model 1 may be due to the difficulty in generating the measure. Since this study is at the firm level, I reconstructed each firm's patent portfolio throughout the observation period. This required an extensive effort and is likely prone to missing patents that the firm has leased an interest in as opposed to having an ownership position. Given this difficulty, it is worth noting that the Ease of Recombination was significant in these models at all. Of more interest though is the direct effect that is observed for the ease of recombination in Table 5.6 model 0. In this model, the ease of recombination has an IRR of .12 which indicates that a unit increase in the ease of recombination would decrease the creation of new primary subclasses by 88%. This is a substantial effect but in the opposite direction expected under the model. The size of the effect is interesting in that it is larger than the effects found related to the number of unique elements. A similar size of effect differential was identified in the recombinant innovation literature (Fleming, 2001) with ease of recombination having a more substantial effect than the number of unique elements. However, the ease of recombination' s negative direct effect is surprising. I can think of two possible explanations for this negative effect. First, a possible explanation may be due to this study's firm level focus as opposed to the innovation level focus previously taken in the recombinant innovation literature (Fleming, 2001; Fleming & Sorenson, 2001). From a portfolio perspective, the addition of a new element that has a high ability to recombine with other elements may generate more local satificing solutions (Winter, 2000) reducing the incentive (Ahuja & Katila, 2004) that drives non local search which leads to exploratory innovation. A second possible explanation is the methodology applied in this study to create the ease of recombination measure. This measure was created by using the relationships identified through prior patent citations and the primary classifications of the cited patents. A much more intensive but detailed methodology would be to use the USPTO sub classifications to create the ease of recombination measure. The significance of the ease of recombination measure along with the questions raised here call for a further examination of this concept, its measure and its effect in a portfolio context.

6.5 Summary of Theoretical and Empirical Contributions

Managerial agency is a central perspective in strategy research but scholars have criticized a lack of understanding of the forces that shape managerial attention (Hutzschenreuter & Kleindienst, 2006). Ocasio's (1997) attention based view of the firm proposed that firm resources were an important influence on managerial attention. This work created a logical bridge between the cognitive and resource based perspectives on strategy but has not been further developed. This gap lead to the research question: What is the influence of a firm's core technical knowledge structure on managerial attention? This dissertation proposed that it is the structure of the firm's resources that influence managerial attention. The analysis supported this overarching position, furthering scholarly literature within both the attention and resource based views by point toward resource structure as an important link these views. However, the structural effect identified is not simple. It appears that similar structural measures can have different effects depending upon their level of measurement. The unusual findings identified in this study call for further research into the resource - attention relationship, described in more detail in the above discussion.

The second main focus of this study is the role of resources and managerial attention on exploratory innovation. The core capabilities and recombinant innovation literatures clearly describe a link between resources and exploratory innovation through search. However, search is a cognitive process and attention as the first step in the cognitive processing model is theoretically important but understudied for its effect on exploratory innovation. This gap lead to the research question: What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes? This dissertation proposed that managerial attention mediated the relationship between resource structure and exploratory innovation. The study found evidence of partial mediation on one structural variable. However, it appeared clearer that these relationships operated differently at different levels. On exploratory innovation that is more distant, stronger theoretical justification supported the role of managerial attention that is more acute, triggered by environmental changes. On exploratory innovation that is more local, the results found a dual path related to resource structure and the more general pattern of managerial attention examined in this study. These findings present a more subtle understanding of the role of managerial attention in the firm's exploratory innovation than that put forth in the attention and innovation literature. This also calls for further research into the relationship between the more acute forms of managerial attention and the broader patterns of managerial attention described in more detail in the above discussion.

Also addressing the second research question, 'What is the relationship of managerial attention and core technical knowledge structure on a firm's exploratory innovation outcomes?', but not hypothesized upon in the model was an examination of two theories that related resource structure to innovation outcomes. This study was the first application of recombinant innovation theories at the firm level. This was compared in the above discussion to the measures taken from the core capabilities literature. In general, the recombinant innovation measures outperformed the core capabilities measures but the results were again not simple. They indicated that the level of the resource's applicability matters to the firms innovative capabilities. The application and significance of the recombinant innovation literature at the firm level is a contribution to innovation theory. Further, the contrasting performance of the core capabilities measures and the recombinant innovation measures calls for further research and a theoretical integration of these two literatures.

In addition to the theoretical contributions above, I make an empirical contributions by developing Ease of Recombination as a portfolio level measure. Previously only applied at the innovation level. Ease of Recombination had a demonstrated impact on the Breadth of Managerial Attention. I did not find a direct effect on the firm's innovation outcomes which calls for additional development of this measure, using more detailed information at the primary subclass level

7. LIMITATIONS

As with all research, this study has limitations. I will address these with respect to the main constructs (attention, structure and innovation) and then the methodology. However, as often is the case, these limitations can also provide opportunities for future research which I will point out.

Managerial attention is a difficult construct to measure as it is multifaceted and ephemeral. Limited direct access to senior management has pushed management scholars to use written secondary. The need for some uniformity in the purpose of the underlying source material has focused scholarly attention on shareholders letters and often a single industry. While these letters may give insight into the thinking of senior management, by their nature, they restrict scholarly attention to publicly held firms. This limits the generalizability of the analysis but opens the possibility further study if access was available at privately held firms. Another limitation of the shareholders letters is that they are not uniformly published by every public firm every year. This is especially true when firms find themselves in more difficult financial positions. This self selection may create a bias in the analysis toward firms that are performing more favorably.

The textural analysis that is necessary to work with shareholders letters presents its own difficulties. The application of qualitative techniques time intensive and fraught with the potential of researcher bias in the establishment of categories and the coding of text. As opposed to this, the application of computer aided techniques are faster, more uniform and more replicable but are not yet able to fully parse the subtlety of written language. This study used a computer based method to estimate, at the word level, broad measures of managerial attention. The application of a more qualitative methodology may be better able to parse the broad measures used into categories which could be more informative about the categories of managerial attention that influence innovation outcomes.

The model presented in this study focused on resource structure as an antecedent of a specific dimension of managerial attention. While this addresses a significant gap in the scholarly literature, this is a very limited model of managerial attention. By focusing on the role of resource structure on managerial attention, other antecedents of managerial attention are not addressed. As I noted in the literature review, managerial attention has been studied in pieces and there is not a unifying. An important development for cognition research would be to move these individual studies toward a single model that incorporates resource structure as well as other antecedents.

This study used patents to dimensionalize technical knowledge. Patents represent one of the best publicly available sources of technical knowledge ownership. However, firm patenting behavior is not uniform. Some firms may patent earlier in the development process than others. While some firms may not patent at all, instead choosing to retain knowledge as a corporate secret. Biotechnology was the setting for this study because the use of patents to protect intellectual property is common. However, the variety in patenting behavior adds uncertainty to the measures of core resource structure.

Patents by their nature, represent explicit knowledge. Tacit knowledge is also important to innovation (Grant, 1996; Nonaka, 1994). Explicit knowledge while related to tacit knowledge (Mowery et al., 1996), may not fully incorporate the firm's core technical knowledge. However, due to the inability to measure or dimensionalize tacit knowledge, scholars focus on explicit knowledge. In this study I took a portfolio perspective of explicit knowledge and dimensionalized this using a firm's patent holdings. This information is not easily obtained. The USPTO does not have records indicating how patent ownership trades hands after the patent is granted. While I used a number of secondary sources to recreate the firm's interest in the patents it did not own it is likely that this information is not fully complete. My focus on existing technical knowledge is logical given its theoretical linkage to innovation through search behaviors. However, firms possess many other resources in addition to their patent portfolios. While I controlled for firm size, in the analysis, it may be that other specific resource categories and their dimensions also contribute to exploratory innovation.

I measured exploratory innovation through the creation of new to the firm patent classes and subclasses. I used these two measures as they represented different levels of exploratory innovation. The creation of a new primary class was considered more exploratory than the creation of a new primary subclass. The creation of new patents represents a formal and explicit type of innovation. As mentioned above, firms exhibit different patenting behaviors and this variation is likely to have impacted the dependent measures. While I focused this study on explicit innovation, this is not the only form of innovation that firms engage in. It is likely that core technical knowledge also influences process innovations that are not captured by patenting behavior. The exploratory innovation captured in the dependent measures may be improved. It is possible to take the new primary class and new primary subclass measures further by examining the relative distance of the new patent to the firm's existing knowledge through the patent's cross reference citations. The creation of such a measure would give a better sense of the relative exploration through the creation of new primary classes and subclasses.

Lastly, due to the issues surrounding the measurement of managerial attention, I conduced this research using a single industry setting. Further, I used an IPO cohort to create my sample as the linkage between resource structure and managerial attention was strongest for 'newer' firms. These methodological choices limit the generalizability of this research but open opportunities to explore these relationships in other industries and in more established firms. It would be interesting to explore the changing role of managerial attention as a firm becomes more established and potentially more routenized.

8. TABLES AND FIGURES

Table 2.1

Attention Definitions

Author	**Definition**
(Fiske & Taylor, 1984, p184)	The degree to which something (an event, trend, idea, category, etc.) occupies the consciousness of individuals.
(Sproull, 1984, p10)	'Allocating information-processing capacity (receiving, cognitive processing, disseminating) to environmental stimuli over time.'
(D'Aveni & MacMillan, 1990, 640)	Cites (Sproull, 1984)
(Abrahamson & Hambrick, 1997)	Cites (Fiske & Taylor, 1984)
(Ocasio, 1997, 189)	'the noticing, encoding, interpreting and focusing of time and effort by organizational decision-makers on both (a) issues: the available repertoire of categories for making sense of the environment; problems, opportunities and threats; and (b) answers; the available repertoire of action alternative; proposals routines, projects, programs and procedures.'
(Levy, 2005)	Cites (Fiske & Taylor, 1984) and (Sproull, 1984)
(Cho & Hambrick, 2006)	Cites (Ocasio, 1997)

Table 2.2

Summary of Theoretical Attention Articles

Author(s)	Key Contribution
(Cyert & March, 1963; March & Simon, 1958b; Simon, 1947)	Human rationality is goal directed but of limited attentional, information processing capability and decision maximizing capacity. Organizations influence individual decision process by allocating and distributing the stimuli that channel the attention of administrators in terms of what selected aspects of the situation are to be attended and what aspects are ignored. Decision-making in organizations is the result of both the limited attentional capacity of humans and the structural influences of organizations on an individual's attention.
(Cohen, March, & Olsen, 1972)	Attention is created through organized anarchy, the interaction of problems, solution, participants and choice opportunities.
(Kahneman, 1973)	Focused attention facilitates perception and action toward the thing being attended to and inhibits perception and action toward things not being attended to.

Table 2.2

Summary of Theoretical Attention Articles (Continued)

Author(s)	Key Contribution
(Miles, Snow, Meyer, & Coleman, 1978)	Managers pay attention to three fundamental organizational problems; defining the market the firm operates within (entrepreneurial problem); creating a system to operationalize the entrepreneurial ides (engineering problem); rationalizing and stabilizing firm activities (administrative problem).
(Pfeffer & Salancik, 1978)	Managers pay attention to external resources they are dependent upon. Attention is focused by the firm's information system, the organizational structure and past decisions. Environmental enactment creates problems when an organization misreads actor's interdependence or demands, is the subject of conflicting demands, or is a victim of past commitments.
(Weick, 1979)	Managers enact their environment by selective attention to environmental stimuli.
(Staw et al., 1981)	When faced with a threatening situation there is a narrowing of attention to dominant or central cues and away from peripheral cues resulting in a decreased ability to discriminate among relevant stimuli.
(Kiesler & Sproull, 1982)	Managerial attention is an individual cognitive and social process driven by aspiration level triggers and the level of signal to noise.
(Schwenk, 1984)	Cognitive simplifications identified in psychology research will exist in manager framing of strategic decisions.
(Fiske & Taylor, 1984)	Focused on social cognition, attention is driven by the relationship of stimuli salience to underlying mental schema and environmental cues.
(Daft & Weick, 1984, p285)	Organizations are complex open systems engaged in a process of information gathering and interpretation. Organizational interpretation is driven by 'a relatively small group at the top of the organizational hierarchy'.

Table 2.2

Summary of Theoretical Attention Articles (Continued)

Author(s)	Key Contribution
(Starbuck & Milliken, 1988)	Executives face unique difficulties in accurately perceiving the competitive environment, especially during periods of turbulant change. Infrequent strategic decision making and the lack of frequent feedback lead to problems in applying schemas developed during periods of stability to occurrences of significant upheaval.
(Gersick, 1994)	Temporal pacing and event pacing act as attention triggers motivating organizational change.
(Ocasio, 1995)	Organizational attention is directed toward the resolution of adversity. The allocation of attention in organizations is an interaction of a cognitive process, a structural process, and an institutional process.
(Ocasio, 1997, p 189 194)	Firms are systems of structurally distributed attention in which the cognition and action of individuals are derived from the specific organizational context and situations that individual decision makers find themselves in. Issues and answers are the cognitive schemas available to decision makers in the firm to make sense of (issues) and to respond to (answers) environmental stimuli.
(Ocasio & Joseph, 2005)	Strategy is an emergent function of the patterns of organizational attention and feedback embedded in the interacting network of operational and governance communication channels within a firm.

Table 2.3

Summary of Empirical Attention Articles

Authors	Method	Sample	Key Variables	Key Findings
(Sproull, 1984)	Case based examination of internal communications.	Seven public sector managers.	IV: Attention- Category of activities. (time spent on an activity).	Decision relevant information is identified by redundancy of transmission, deadlines and communication by trusted parties in the social network.
(D'Aveni & MacMillan, 1990)	5 yr longitudinal Matched pair. Hazard model.	57 failed/ survivor firms	IV: Attention- external vs internal, output vs input. (Content analysis of letter to shareholders) DV: Survival	Managers of surviving firms pay greater attention to the output factors and the external environment. Managers of failing firms pay more attention to the input and internal environment.
(Abrahamson & Hambrick, 1997)	Archival, correlation	14 industries that vary in discretion	Industry Discretion Lexical commonality Lexical density (computer based word count of annual letter to shareholders)	Industries with higher levels of managerial discretion have a higher degree of managerial attention heterogeneity. Industries with low levels of managerial discretion have greater homogeneity of managerial attention.
(March et al., 2000)	Archival, 100 yr longitudinal, Hazard rate model.	Stanford Univ governing bodies - agendas	IV: Attention (measured by formal agenda items) DV: Rule birth and rule changes	Formalized attention impacts organizational learning. Positive effect of attention to rules on rule births and on rule changes.

Table 2.3

Summary of Empirical Attention Articles (Continued)

Authors	Method	Sample	Key Variables.	Key Findings
(Levy, 2005)	Archival, 7 yr longitudinal	69 firms 3 tech intensive ind. Computer, Pharma, semiconductor	IV: Attention focus- external vs internal IV: Attention Breadth – Herfindal-Hirschman index predefined categories. (Content analysis of annual letter to shareholders.) DV: Global strategic posture	Top management teams that focus on the external environment and attend to diverse elements in the environment are more likely to pursue expansive strategic postures. In dynamic environments, managerial attention plays an important role in shaping strategic choices of firms.
(Cho & Hambrick, 2006)	Archival, 13 year longitudinal	30 large US airlines operating during period of deregulation.	IV: Entrepreneurial Orientation (Word Count analysis letter to shareholders) IV: TMT Demographics IV: Performance Dependent Pay DV: Realized entrepreneurial strategy	Environmental change (deregulation) shifts managerial attention. Changes in composition or compensation of a TMT impacts managerial attention. Composition and compensation positively interact on attention. Managerial attention partially mediates the relationship between managerial demography, pay arrangements and company strategy.
(Yu et al., 2005)	Qualitative 7 yr longitudinal	Post merger in Healthcare industry.	Attention measured by time allocated in bi-weekly meetings.	Daily demands distract from attention focus on original merger impetus. Persistent mental models can generate conflict especially when underlying organizational support systems reinforce the older mental models.

Table 2.3

Summary of Empirical Attention Articles (Continued)

Authors	Method	Sample	Key Variables.	Key Findings
(Hung, 2005)	Qualitative- Interviews and archival sources (newspapers, etc.)	Seven Taiwanese PC firms mid 1990s.	IV: Linkage to Policy system (the state) IV: Linkage to Business system (business networks) DV: Attention to Policy system, Attention to Business system	The higher the degree of institutional embeddedness, the more the organization will attend to and be shaped by the prevailing institutional environment (policy system and business system).
(Howard-Grenville, 2006)	Ethnographic	Single computer chip manufacturer	IV: Subculture IV: Power DV: Attention, issue interpretation, strategic option choice.	Power differential between subcultures within an organization influences organizational attention, issue interpretation and action strategy adoption.
(Yadav et al., 2007)	Quantitative, Longitudinal	176 banks during ATM introduction.	IV: Future, internal, external (focus of attention) DV: speed of detection, speed of development, breadth of deployment	Attention to the future as well as the internal and external environment influenced the speed of detection and speed of development of internet banking. Senior manager attention to the future was also influential on the breadth of deployment of internet banking.

Table 2.3

Summary of Empirical Attention Articles (Continued)

Authors	Method	Sample	Key Variables.	Key Findings
(Eggers & Kaplan, 2008)	Quantitative, longitudinal, hazard model.	29 public communication tech firms entering fiber optics. 1985-1976	IV: Organizational Orientation (patent data) IV: CEO attention (Word Count analysis of Letter to Shareholders) DV: introduction of fiber optic product.	CEO attention to emerging technology and the impacted industry accelerate product entry. CEO attention to existing technologies delays product entry. CEO attention is most relevant in situations where basic organizational components in the emerging technology are lacking
(Kaplan, 2008)	Quantitative, longitudinal, random effects, Censored Tobit regression	71 public communication tech firms during fiber optic revolution. 1982-2001	IV: CEO attention (Word count analysis Letter to Shareholders) IV: Organizational capabilities (years of optical product experience) IV: Incentives (sales to carriers) DV: Investment in optical technology (optical patents)	CEO attention is positively associated with lagged changes in optical patenting. Changes in CEO attention have the least impact on firm technical investment when incentives or capabilities in the focal arena are high.

Table 2.4

Focus of Empirical Attention Articles

Authors	Impact on Attention	Impact of Attention
(Sproull, 1984)	X	
(D'Aveni & MacMillan, 1990)		X
(Abrahamson & Hambrick, 1997)		X
(March et al., 2000)		X
(Levy, 2005)		X
(Cho & Hambrick, 2006)	X	X
(Yu et al., 2005)	X	
(Hung, 2005)	X	
(Howard-Grenville, 2006)	X	X
(Eggers & Kaplan, 2008)		X
(Kaplan, 2008)		X
(Yadav et al., 2007)		X

Table 4.1

Summary of Core Technical Knowledge Structure Measures

<table>
<tr><th>Abbreviation</th><th>Variable</th><th>Description</th></tr>
<tr><td>#UqPC</td><td>Number of Unique Primary Classifications</td><td>The number of unique primary classifications represents at a high level the number of separate core technical knowledge elements that the firm has available for recombination in the innovation process.</td></tr>
<tr><td colspan="3">$$NoUqPC = \sum upc_{ti}$$ where '*upc*' represents a single primary classification where firm '*i*' has an interest in at least one patent during time period '*t*'. This variable includes patents that the firm acquired through other means (merger /acquisitions /IP agreements).</td></tr>
<tr><td>#UqPS</td><td>Number of Unique Primary sub classifications</td><td>The number of unique primary sub classifications represents at a more fine grained level the number of separate core technical knowledge elements that the firm has available for recombination in the innovation process.</td></tr>
<tr><td colspan="3">$$NoUqS = \sum ups$$ where '*ups*' represents a single primary sub classification where firm '*i*' has an interest in at least one patent during time period '*t*'. This variable includes patents that the firm acquired through other means (mergers /acquisitions /IP agreements).</td></tr>
</table>

Table 4.1 (Continued)

Summary of Core Technical Knowledge Structure Measures

<table>
<tr><th>Abbreviation</th><th>Variable</th><th>Description</th></tr>
<tr><td>PCConc</td><td>Primary Class Concentration, log transformation</td><td>Concentration at the primary classification level represents the way the firm has distributed its core technical knowledge.</td></tr>
<tr><td colspan="3">PCConc = $\sum_1^j QPC_{ij}^2$
where ‘QPCij’ denotes the percentage of patents within primary classification *‘i’* within a portfolio of *‘j’* total primary classifications. (A Herfindahl type concentration formula)</td></tr>
<tr><td>PSConc</td><td>Primary Subclass Concentration, log transformation</td><td>Concentration at the primary sub classification level represents a finer grained measure of the way the firm has distributed its core technical knowledge.</td></tr>
<tr><td colspan="3">PSConc = $\sum_1^j QPS_{ij}^2$
where ‘QPSij’ denotes the percentage of patents within primary sub classification *‘i’* within a portfolio of *‘j’* total primary sub classifications.</td></tr>
<tr><td>EaseRAvg</td><td>Ease of Recombination, Average</td><td>Ease of Recombination, Average is a measure of how easily an the average knowledge element is combined with other knowledge elements.</td></tr>
</table>

Table 4.2

Summary of Managerial Attention Measures

<table>
<tr><td>Abbreviation</td><td>Variable</td><td>Description</td></tr>
<tr><td>Commonality</td><td>Lexical Commonality</td><td>Commonality measures the intensity (frequency) of concepts (words) being used by a firm as compared to the use of those concepts by competitor firms.</td></tr>
<tr><td colspan="3">$$Cmnlty = \sum_{i}^{n} Fw_i * Qw$$
The summation for all words 'n' in a shareholders letter, where 'Fwi' represents the frequency of use of word 'w' occurring in shareholders letter 'i' and 'Qw' represents the proportion of shareholders letters that also used word 'w'</td></tr>
<tr><td>Density</td><td>Lexical Density</td><td>Density measures the occurrence (binary) of a concept (word) used by a firm as compared to its maximum possible occurrence in all competitor firms.</td></tr>
<tr><td colspan="3">$$Density = \sum_{1}^{n} \frac{SAw}{SMw}$$
Where 'SAw' represents the number of firms that share word 'w' and 'SMw' represents the potential maximum number of firms that could share word 'w'.</td></tr>
</table>

Table 4.3

Simple Example of Calculation of Lexical Commonality

Word	Letter 1	Letter 2	Letter 3	Word Commonality
Sales	3	10	1	100%
Assets	4			33%
Costs	5	2	1	100%
Margins		3	1	66%
Letter Commonality	((3x100%) +(4x 33%) +(5x100%)) / (3+4+5)	((10x 100%) +(2x 100%) +(3x 66%)) / (10+2+3)	((1x 100%) +(1x 100%) +(1x 66%)) / (1+1+1)	
	78	93	89	

Reproduced from Abrahamson and Hambrick (1997)

Table 4.4

Simple Example of Calculation of Lexical Density

Word	Ltr 1	Ltr 2	Ltr 3	No of Co that used word	Actual Combos[1]	Potential Combos[2]	Actual /Potential
Sales	Yes	Yes	Yes	3	3	3	1
Assets	Yes			1	0	3	0
Costs	Yes	Yes	Yes	3	3	3	1
Margins		Yes	Yes	2	1	3	.33
Lexical Density	1+0 +1=2	1+1+.33 =2.33	1+1+.33 =2.33				

1 - Actual Combinations are the number of binary combinations available based upon the number of firms that used the word.

2 – Potential Combinations are the number of binary combinations available based upon the number of firms in the sample.

Table 4.7

Summary of Innovation Measures

<table>
<tr><td>Variable</td><td>Description</td><td></td></tr>
<tr><td>#NwPC</td><td>Number of New Primary Classes</td><td>#NwPC represents the firm expanding their capabilities by adding new knowledge in a new area.</td></tr>
<tr><td colspan="3">$\#NwPC = \sum NPC$
NPC = 1 if (PCt ≠ PCt-1)
NPC = 0 if (PCt = PCt-1)
where ‘PC’ represents the portfolio of unique primary classifications at time period ‘t’. This variable does not include patents that the firm acquired through other means (mergers/acquisitions/IP agreements).</td></tr>
<tr><td>#NwPS</td><td>Number of New Primary Subclasses</td><td>#NwPS represents the firm expanding and deepening their capabilities with an area (patent class) they already have experience.</td></tr>
<tr><td colspan="3">$\#NwPS = \sum pas_{ti}$
where ‘pas’ represents an assigned patent with a Primary Subclassification that is new to firm ‘i’ and whose application date is within time period time period ‘t’. This variable does not include patents that the firm acquired through other means (mergers/acquisitions/IP agreements).</td></tr>
</table>

Table 4.8

Summary of Controls

Control	Measure
Firm Size	Natural log of total assets
Prior Patents	Natural log of the number of patents assigned to a firm
2000-2001	Binary control for period 2000-2001

Table 5.1

Descriptive Statistics

	Variable	N	Mean	Std. Dev	Min	Max
Independent Variables: Managerial Attention	Lexical Commonality	176	268.23	119.25	55.97	751.11
	Lexical Density	176	98.53	24.03	38.06	171.66
Independent Variables: Core Technical Knowledge Structure	No. of Unique Primary Classes	359	6.82	5.28	1.00	35.00
	No. of Unique Primary Subclasses	359	25.44	31.55	1.00	259.00
	PC Concentration	359	0.45	0.18	0.12	1.00
	PS Concentration	359	0.15	0.15	0.02	0.78
	Ease Recombination	359	.07	.12	0.005	.50
Dependent Variables	No. of New Primary subclasses	319	1.75	3.29	0.00	27.00
	No. of New Primary Classes	294	0.23	0.58	0.00	4.00
Controls	Total Assets	336	135.36	371.9	0.139	3997.61
	Number of Patents	359	55.97	85.3	1.0	735.0

Table 5.2

Pair wise Correlations, 40 firms (1997-2001)

	1	2	3	4	5	6	7	8	9	10
1. NoNwPS	1.00									
2. BNwPC	.45***	1.00								
3. Commonality	.24**	.11	1.00							
4. Density	.20*	.08	.93***	1.00						
5. #UqPC	.62***	.16**	.25***	.22**	1.00					
6. #UqPS	.59***	.06	.28***	.23**	.89***	1.00				
7. PCConc	-.25***	-.13*	-.26***	-.22**	-.55***	-.35***	1.00			
8. PSConc	-.23***	-.07	-.07	-.09	-.42***	-.34***	.48***	1.00		
9. EaseRAvg	-.01	.01	-.02	-.06	-.05	-.05	-.05	.14**	1.00	
10. NP[1]	.39***	-.06	.08	.08	.71***	.71***	-.34***	-.49***	-.18***	1.00
11. TtlAsts[1]	.38***	.11*	.14+	.17*	.54***	.52***	-.36***	-.48 ***	.11*	.46***

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.2 (1997)

Pair wise Correlations, 40 firms (1997)

	1	2	3	4	5	6	7	8	9	10
1. NoNwPS	1.00									
2. BNwPC	.53***	1.00								
3. Commonality	.07	.01	1.00							
4. Density	.08	-.04	.96***	1.00						
5. #UqPC	.64***	.37*	.15	.13	1.00					
6. #UqPS	.65***	.20	.15	.15	.93***	1.00				
7. PCConc	-.29+	-.30+	-.21	-.14	-.67***	-.52***	1.00			
8. PSConc	-.27+	-.16	-.11	-.11	-.46**	-.46**	.53***	1.00		
9. EaseRAvg	-.04	.00	.07	.07	-.04	-.13	-.10	.27+	1.00	
10. NP[1]	.39*	-.01	.07	.02	.61***	.73***	-.30+	-.43**	-.28+	1.00
11. TtlAsts[1]	.43**	.23	.10	.15	.38*	.40*	-.23	-.41*	.12	.43**

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.2 (1998)

Pair wise Correlations, 40 firms (1998)

	1	2	3	4	5	6	7	8	9	10
1. NoNwPS	1.00									
2. BNwPC	.42**	1.00								
3. Commonality	.26	.08	1.00							
4. Density	.28+	.17	.93***	1.00						
5. #UqPC	.78***	.24	.25	.29+	1.00					
6. #UqPS	.82***	.14	.24	.29+	.93***	1.00				
7. PCConc	-.33*	-.23	-.43**	-.42*	-.65***	-.48**	1.00			
8. PSConc	-.29+	-.15	-.19	-.23	-.46**	-.45**	.50**	1.00		
9. EaseRAvg	.04	-.07	-.07	-.13	-.03	-.08	-.06	.28+	1.00	
10. NP[1]	.43**	-.11	.06	.16	.66***	.76***	-.33*	-.55***	-.20	1.00
11. TtlAsts[1]	.47**	.22	.43**	.53***	.47**	-.45**	-.43**	-.43**	.06	.39*

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.2 (1999)

Pair wise Correlations, 40 firms (1999)

	1	2	3	4	5	6	7	8	9	10
1. NoNwPS	1.00									
2. BNwPC	.57***	1.00								
3. Commonality	.36*	.35+	1.00							
4. Density	.30+	.25	.88***	1.00						
5. #UqPC	.68***	.33*	.41*	.41*	1.00					
6. #UqPS	.83***	.40*	.40*	.38*	.93***	1.00				
7. PCConc	-.20	-.34*	-.34+	-.31+	-.61***	-.42**	1.00			
8. PSConc	-.30+	-.26	.16	-.06	-.44**	-.39*	.46**	1.00		
9. EaseRAvg	-.04	-.01	-.12	-.22	-.04	-.08	-.03	.34*	1.00	
10. NP[1]	.48**	.20	.14	.21	.71***	.74***	-.33*	-.54***	-.25	1.00
11. TtlAsts[1]	.49**	.16	.06	.18	.56***	.57***	-.31*	-.51***	.06**	.51***

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.2 (2000)

Pair wise Correlations, 40 firms (2000)

	1	2	3	4	7	8	9	10	11	12
1. NoNwPS	1.00									
2. BNwPC	.29+	1.00								
3. Commonality	.45*	.30	1.00							
4. Density	.34+	.28	.96***	1.00						
5. #UqPC	.77***	.16	.46*	.39*	1.00					
6. #UqPS	.88***	.18	.54**	.44*	.92***	1.00				
7. PCConc	-.28+	.05	-.05	-.05	-.58***	-.39*	1.00			
8. PSConc	-.23	-.15	-.29	-.24	-.42**	-.34*	.48**	1.00		
9. EaseRAvg	-.01	.19	-.08	-.12	-.11	-.12	.09	.25	1.00	
10. NP[1]	.49**	-.03	.31	.25	.71***	.74***	-.35*	-.47**	-.30+	1.00
11. TtlAsts[1]	.48**	.24	.32+	.23	.52**	.49**	-.40*	-.46**	-.01	.40*

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.2 (2001)

Pair wise Correlations, 40 firms (2001)

	1	2	3	4	5	6	7	8	9	10
1.NoNwPS	1.00									
2.BNwPC	.75***	1.00								
3.Commonality	.25	-.07	1.00							
4.Density	.18	-.08	.96***	1.00						
5. #UqPC	.75***	.54***	.24	.24	1.00					
6. #UqPS	.83***	.52**	.47*	.47*	.93***	1.00				
7.PCConc	-.26	-.08	-.50*	-.44*	-.50**	-.34*	1.00			
8.PSConc	-.29+	-.14	-.61**	-.67***	-.37*	-.31+	.38*	1.00		
9.EaseRAvg	-.08	-.10	-.15	-.19	-.13	-.13	-.05	.09	1.00	
10.NP[1]	.58***	.32+	.31	.40+	.72***	.76***	-.29+	-.38*	-.43*	1.00
11. TtlAsts[1]	.46**	.40*	.23	.27	.52**	.47**	-.32+	-.50**	.03	.42*

[1] Entered as a natural log

*** Significant at the .001 level – 2 tailed

** Significant at the 0.01 level - 2 tailed

* Significant at the 0.05 level - 2 tailed

+ Significant at the 0.10 level - 2 tailed

Table 5.3

Results of Panel data Linear Regression Examining the relationship between Core Technical Knowledge Structure and the Breadth of Managerial Attention

(significant p values in parenthesis)

	1 Lexical Commonality	2 Lexical Density
Independent Variables		
No. Unique PC	-18.7 (.07)	-3.2
No. Unique PS	4.7 (.01)	0.72 (.05)
Primary Class Conc.	-175.1	-46.6
Primary Subclass Conc.	478.1 (.02)	98.6 (.02)
Ease Recombination	602.1 (.05)	144.3 (.02)
Constant	255.8 (.07)	114.1 (.000)
Controls		
# of Patents	.28	-4.1
Total Assets	-.94	-0.03
2000- 01	2.64	0.72
# of Obs	175	175
# of Firms	40	40
R^2	.12[1]	.12[1]
Model	Fixed	Fixed
F	2.26 (.027)	2.18 (.03)
Wald Chi^2		

1) Within 2) Overall

Table 5.3 (1)

Results of Panel data Linear Regression Examining the relationship between Core Technical Knowledge Structure and the Breadth of Managerial Attention

(significant p values in parenthesis)

One year Lag	1 Lexical Commonality	2 Lexical Density
Independent Variables		
No. Unique PC	-9.5 (.07)	-.9
No. Unique PS	3.3 (.001)	.4 (.04)
Primary Class Conc.	-247.5(.001)	-36.5 (.02)
Primary Subclass Conc.	50.5	4.6
Ease Recombination	-111.4	-24.2
Constant	455.7(.000)	124.8(.000)
Controls		
# of Patents	-35.2 (.03)	-5.9 (.09)
Total Assets	8.6	2.1
2000- 01	-11.9	-2.9
# of Obs	168	168
# of Firms	40	40
R^2	.17[1]	.12[1]
Model	Random	Random
Wald Chi^2	28.7(.000)	17.5(.025)

1) Overall 2) Within

Table 5.3 (2)

Results of Panel data Linear Regression Examining the relationship between Core Technical Knowledge Structure and the Breadth of Managerial Attention, Reduced n for mediation analysis

(significant p values in parenthesis)

Limited n for mediation analysis	1 Lexical Commonality	2 Lexical Density
Independent Variables		
No. Unique PC	-9.9 (.09)	-1.3
No. Unique PS	3.7 (.003)	0.54 (.04)
Primary Class Conc.	-204.7(.01)	-30.6 (.08)
Primary Subclass Conc.	120.2	17.1
Ease Recombination	-113.6	-24.9
Constant	351.8 (.000)	106.0 (.000)
Controls		
# of Patents	-26.1	-4.3
Total Assets	17.1	4.3 (.06)
2000- 01	-16.6	-5.2
# of Obs	157	157
# of Firms	40	40
R^2	$.18^2$	$.14^2$
Model	Random	Random
Wald Chi^2	25.07(.001)	16.34 (.037)

Table 5.4

Comparison of Count vs Binary Variable for the Creation of New Primary Classes

Number of New PC				Binary New PC		
	Frequency	Percent			Frequency	Percent
0	245	83.33		0	245	83.33
1	36	12.24		1	49	16.67
2	9	3.06				
3	3	1.02				
4	1	0.34				
Total	294	100.00		Total	284	100.00

Table 5.5

Results of Panel Data Regression Examining the Mediational Influence of the Breadth of Managerial Attention on Exploratory Innovation Outcomes, Binary New Primary Class

(p values in parenthesis)

New Patent Class	0	1	2
No Unique PC[2]	1.23 (.01)	1.10	
No Unique PS[2]	.98	1.01	
PC Concentration[2]	4.73	6.4	
PS Concentration[2]	.10	.01	
Ease of Recombination[2]	.12	.13	
Commonality[1]			.99
Density[1]			1.05
Control Variables			
Total Assts[2,3]	1.54 (.01)	1.48 (.08)	1.69 (.06)
Number of Patents[2,3]	.25(.000)	.23 (.001)	.43 (.04)
D2000-01	.84	.66	1.10
Model	Panel Logit	Logit	Panel Logit
# of Obs	290	157	157
# of Firms	n/a	n/a	40
Specification	Pooled	Pooled	Random
Chi[2]	30.8 (.000)	19.78 (.01)	6.99

[1] 2 year lag. [2] 1 year lag, [3] Natural log

Table 5.6

Results of Panel Data Regression Examining the Mediational Influence of the Breadth of Managerial Attention of Exploratory Innovation Outcomes, Number of New Patent Subclasses

(p values in parenthesis)

Number of New PS	0	1	2	3
No Unique PC[2]	1.13 (.000)	1.17 (.001)		1.14 (.009)
No Unique PS[2]	.98 (.000)	.98 (.004)		.98 (.06)
PC Concentration[2]	2.78	8.38 (.06)		8.34 (.06)
PS Concentration[2]	.84 (.06)	.12		.10
Ease of Recombination[2]	.12 (.01)	.14		.18
Commonality[1]			.99 (.003)	.99 (.04)
Density[1]			1.03 (.002)	1.02 (.02)
Control Variables				
Total Assts[2,3]	1.29 (.01)	1.21	1.19 (.02)	1.23 (.08)
Number of Patents[2,3]	.76	.85	1.20	.89
D2000-01	1.06	.92	.99	1.01
Model	Panel Negative Binomial			
# of Obs	290	157	157	157
# of Firms	40	40	40	40
Specification	Random	Random	Random	Random
Wald Chi[2]	28.76 (.000)	20.36 (.009)	14.14 (.015)	25.95 (.004)

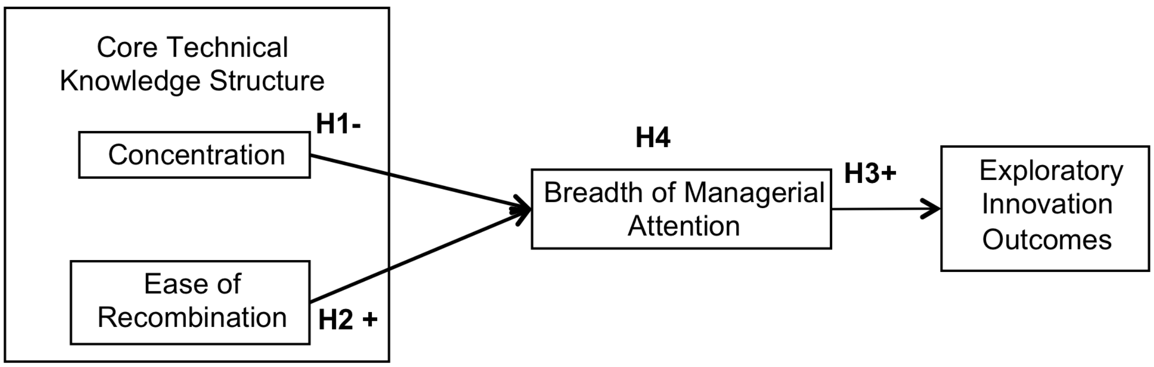
[1] 2 year lag. [2] 1 year lag, [3] Natural log

Table 5.7
Summary of Results for Hypothesis 1-4

H	Independent Variable / Mediator	Dependent Variable	Predicted Sign	Results
1	Primary Class Concentration	Lexical Commonality	-	Supported (p.001 in lag)
		Lexical Density	-	Supported (p.02 in lag)
	Primary Subclass Concentration	Lexical Commonality	-	Not Supported, Sign reversed (p .02)
		Lexical Density	-	Not Supported, Sign reversed (p .02)
	Number of Unique Primary Classes	Lexical Commonality	+	Not Supported, Sign reversed (p .07)
		Lexical Density	+	
	Number of Unique Primary Subclasses	Lexical Commonality	+	Supported (p. 01)
		Lexical Density	+	Supported (p .05)
2	Ease of Recombination	Lexical Commonality	+	Supported (p .05)
		Lexical Density	+	Supported (p .02)
3	Lexical Commonality	Binary New Prim Class	+	
		Num Unique Sub Class	+	Not Supported, Sign reversed (p .005)
	Lexical Density	Binary New Prim Class	+	
		Num Unique Sub Class	+	Supported (p .004)
4	Lexical Cmnlty Lexical Density	Creation of a new Primary Class (BNwPC)	Full mediation	
	Lexical Cmnlty Lexical Density	Number of New Patent Subclasses (NoNWPS)	Full mediation	Partial Mediation

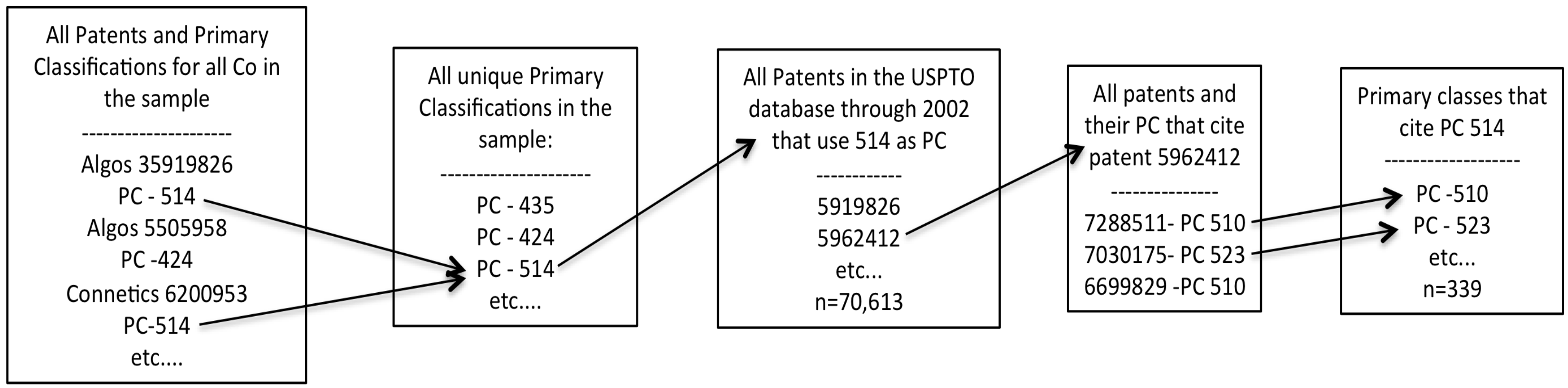
Table 5.12

Figure 1



Research Model

Figure 2



Calculation of Ease of Recombination

Primary Classification -514 has been cited by 339 other Primary Classifications and has been used to classify 70,613 patents. PC-514 has an Ease of Recombination score of 339 / 70,613 = .00

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