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LEARNING TO INNOVATE

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LEARNING TO INNOVATE: The role of ambidexterity, standard, and decision process

Maggie Qiuzhu Mei

The PhD School of Economics and Management

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ENGLISH SUMMARY

Innovation is the engine of sustained organizational performance and is central to organizations' competitive advantage. In an effort to understand how to foster innovation at firms, extant research has highlighted the role of organizational learning in shaping innovation capabilities at firms. Motivated by the importance of innovation, this PhD dissertation aims to improve our understanding of the complex relationship between organizational learning and innovation capabilities at firms.

The dissertation consists of three studies using various datasets and methodologies that investigate the relationship between organizational learning and innovation creation in an organizational context. Taking a nuanced view of organizational learning, the dissertation investigates how three different organizational learning processes could affect innovation creation at the firm level and project level. Specifically, essay 1 focuses on how to manage ambidextrous learning for superior radical and incremental innovation capabilities; essay 2 examines how learning through knowledge sharing in the context of standard setting impacts on firms' innovation performance; and essay 3 moves down to project level and explores how and when strategic decision comprehensiveness can affect new product development performance.

Taken together, though examining three separate approaches that firms employ to manage organizational learning for innovation creation, the three studies in this dissertation collectively contribute to the understanding of managing organizational learning for innovation creation at firms. The three studies in this dissertation show how three prominent organizational learning processes impact on firms' innovation performance. Furthermore, the studies in this dissertation emphasize that there are limitation and boundary conditions for different organizational learning processes.

DANISH SUMMARY

Innovation er motoren bag organisationers vedvarende præstation og er central i forhold til en organisations konkurrencemæssige fordele. I forsøget på at forstå, hvordan man fremmer innovation i firmaer, har omfattende undersøgelser understreget den organisatoriske lærings rolle i udformningen af innovative kapaciteter. Med vigtigheden af innovation som bagvedliggende motivation, forsøger denne ph.d.-afhandling, at forbedre vores forståelse af det komplekse forhold mellem organisatorisk læring og innovative kapaciteter i firmaer.

Denne afhandling består af tre studier, med forskellige data og metoder, som alle søger at belyse forholdet mellem organisatorisk læring og innovativ kreativitet i en organisatorisk kontekst. Idet den kigger nuanceret på organisatorisk læring, forsøger denne afhandling at undersøge, hvorledes tre forskellige organisatoriske læringsprocesser kan påvirke den innovative kreativitet på virksomheds- og projektniveau. Mere specifikt, så fokuserer essay 1 på hvordan man administrerer ambidekstral læring, med henblik på superior radikale og inkrementel innovative kapaciteter; essay 2 undersøger hvordan læring uddraget gennem videndeling i standardiseringen påvirker en virksomheds innovative præstationer; i essay 3 bevæger afhandlingen sig ned på projektniveau og udforsker hvorledes og hvornår en strategisk beslutnings alsidighed kan påvirke præstationerne indenfor produktudvikling.

Samlet set, ved at undersøge disse tre tilgange som firmaer anvender til at administrere organisatorisk læring i forbindelse med innovation og udvikling, bidrager de tre studier i denne afhandling til forståelsen af, hvordan man i firmaer anvender den organisatoriske læring til kreativ innovation. De tre studier i denne afhandling viser, hvordan tre fremtrædende organisatoriske læringsprocesser påvirker firmaers innovative præstationer. Ydermere, så sigter disse studier på at grænserne og vilkårene for de forskellige organisatoriske læringsprocesser.

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Copenhagen, January 23, 2014

Maggie Qiuzhu Mei

CONTENTS

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The fundamental purpose of strategic management theory and research is to explain how and why there are differences in firms' performance. During the past decades, the knowledge-based view (KBV) has emerged as a most influential theoretical perspective regarding sources of competitive advantage. Emphasizing that superior value creation is a function of a firm's ability to access, create, and utilize knowledge (Grant, 1996a, b; Nonaka, 1994), it is argued that the firm will enjoy competitive advantage if it is able to disseminate and exploit organizational knowledge internally (e.g., Argote & Ingram, 2000; Zollo & Winter, 2002), if it is able to protect its knowledge from expropriation and imitation by competition (e.g., King, 2007; Teece, Pisano, & Shuen, 1997), and if it is able to share with, transfer to, and receive knowledge from external partners effectively (e.g., Argote & Ingram, 2000; Wijk, Jansen, & Lyles, 2008).

In an environment characterized by continuously increasing rates of change, firms need to innovate in order to stay competitive. Heralded as the engine of sustained organizational performance, innovation is considered central to organizations' competitive advantage (Dutta, Narasimhan, & Rajiv, 2005; Geroski, Machin, & Reenen, 1993; Hall, 2000). Mirroring the

importance of innovation for firm performance and the fact that most firms find innovation to be a challenging task, innovation research stands as a central pillar of the strategic management literature (Anderson, De Dreu, & Nijstad, 2004).

Building upon the knowledge-based view (KBV) of the firm, innovation in products and services is largely believed to stem from a firm's learning capabilities. For example, Cohen and Levinthal (1990) consider the prior related knowledge within a firm, the absorptive capacity, as an important indicator of the innovative capabilities of the organization. Nonaka (1994) suggests knowledge creation to be at the heart of innovation processes. Moreover, Leonard-Barton (1995) regards knowledge as the main building block for sustaining innovation. Grant (1996a, b) argues that a primary task of the firm is to integrate specialized knowledge and that there are important differences in the efficiency, scope, and flexibility of knowledge integration between firms.

Despite the consensus that organizational learning plays a key role in the development of innovation in firms, it remains intriguing and fundamental to understand why some firms are better at learning and innovation than others. Filling this knowledge gap, however, is not an easy task. One challenge in addressing this question may concern the complicated nature of organizational learning and the vague understanding of the concept itself (Lähteenmäki, Toivonen, & Mattila, 2001). For example, the existing literature generally assumes that organizational learning improves performance without acknowledging that one dimension of organizational learning is that organizations learn bad habits as well (Miner & Mezias, 1996). To echo this point, Inkpen and Crossan (1995) decsribe the lack of understanding of organizational learning using the following metaphor:

> "When an evolving and enhanced understanding is translated into action, organization learning is like the fountain of youth: it represents the organization's ability to undergo continual renewal, thereby prolonging the organization's life indefinitely. Unfortunately, understanding organization learning has been almost as elusive as beating the fountain of youth." (Inkpen & Crossan, 1995, p. 597)

For this reason, it is important to take a nuanced approach to studying the link between organizational learning and innovation, which is the starting point of this dissertation. Specifically, viewing organizational learning as a process, the studies in this dissertation examine the complex relationship between organizational learning and innovation by focusing on three prominent organizational learning processes: ambidextrous learning, learning through knowledge sharing during standard-setting, and learning by being comprehensive during new product decision making. Specifically, essay 1 focuses on how to manage ambidextrous learning for superior radical and incremental innovation capabilities; essay 2 examines how learning through knowledge sharing in the context of standard setting has an impact on firms' innovation performance; and essay 3 further explores how and when strategic decision comprehensiveness can affect new product development performance.

According to Huber (Huber, 1991, p.107), "there is little in the way of substantiated theory concerning organizational learning and there is considerable need and opportunity to fill in the many gaps." Arguing that organizational learning is a rich and complex concept, this dissertation aims to offer a more nuanced view of how firms can manage organizational learning for superior innovation performance. Building on the KBV, the three studies of this dissertation show how three prominent organizational learning processes – ambidextrous learning, learning through knowledge sharing during standard-setting, and learning by being comprehensive during new

product decision making – will have an impact on firms' innovation performance. Taking the nuanced view of organizational learning, the studies in this dissertation emphasize that there are limitation and boundary conditions for different types of organizational learning. I believe that the findings and the approach of this dissertation will extend and enrich the knowledge-based view and in the meantime advance our understanding of the relationship between organizational learning and innovation.

1.2 Literature gaps and research questions addressed in this dissertation

While all three studies fit within the main topic of this dissertation, they address different literature gaps. Essay 1 addresses an important lacuna in the ambidexterity literature – i.e., what is the role of ambidextrous learning in the building of firms' innovation capabilities? Arguing that exploration is related to the development of radical innovation and exploitation to the development of incremental innovation, the literature assumes that ambidextrous firms can pursue different types of innovation effectively, and operationalizes ambidexterity in terms of both exploitative/explorative learning (e.g., Lavie, Stettner, & Tushman, 2010; Rothaermel & Alexandre, 2008) and incremental/radical innovation (Cao, Gedajlovic, & Zhang, 2009; He & Wong, 2004; Jansen, Simsek, & Cao, 2012). However, in keeping with (March, 1991), He and Wong (2004: 485) state explicitly that "exploration and exploitation should be used with reference to a firm's ex-ante strategic objectives in pursuing innovation, whereas the radical versus incremental innovation is often used in an ex-post outcome sense." Treating exploitation and exploration as equivalent to incremental innovation and radical innovation, respectively, overlooks at least two effects. First, in addition to the links between exploitation and firms' incremental innovation capability, and exploration and firms' radical innovation capability, there might be other influential links. For example, exploitation might affect firms' radical innovation

capability by promoting a competency trap (Leonard-Barton, 1992) or reduced absorptive capacity (Cohen & Levinthal, 1990); exploration might have an impact on incremental innovation capability through the contributions of multiple sources to the "fine-tuning" of new products (Laursen & Salter, 2006) and keeping the firm "abreast of development for improving current operations" (Dewar & Dutton, 1986: 1424). Second, beyond the direct effects of exploration and exploitation, the ambidexterity literature highlights the interaction effect between exploration and exploitation on performance outcomes (e.g., Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004). Several scholars argue that exploitation and exploration are non-substitutable and interdependent constructs, providing strong empirical evidence that their co-existence means they should be treated as an integral concept, i.e., ambidexterity. Given that ambidexterity is regarded as an emerging research paradigm in organizational theory (Raisch & Birkinshaw, 2008) and is part of the many prescriptions for firm performance, improvement, and survival (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996), it becomes important to investigate its impacts on the incremental and radical innovation capabilities of firms.

Study 2 addresses the lack of research on standard participation as a technology strategy (Leiponen, 2008). Standard participation is defined as having one's technology successfully included in a standard. The impact on a firm of being included in or excluded from an important standard can be substantial. On the one hand, it can be particularly lucrative for firms to out-license standards related to intellectual property rights. On the other hand, standards favor one firm's technologies, yielding competitive advantage for that firm because other competing technologies are locked out of the market. Thus, some authors suggest that the influence over which standards are developed and adopted is an important aspect of performance for high-

technology firms (Dokko & Rosenkopf, 2009). Despites its significance, standard participation is still "an important but understudied aspect of technology strategy" (Leiponen, 2008). This paper extends the stream of empirical research on standard participation by focusing on two issues. First, how does standard participation affect the innovation rate and direction of a participating firm? Second, what are the interactive effects of internal R&D and standard participation on the rate and direction of innovation of a participating firm? To summarize, this paper provides some quantitative evidence on the costs of standard participation, which managers should weigh against the benefits of participation.

Study 3 addresses the need for a better understanding of how and when strategic decision comprehensiveness (SDC) leads to new product performance. Defined as the extent to which decision makers attempt to be exhaustive or inclusive in information processing when making decisions, SDC appears to facilitate new product development by increasing new product development speed (Eisenhardt, 1989), reducing the effects of cognitive biases associated with new product development, such as escalation of commitment (Miller, 2008), and enhancing managers' confidence in undertaking risky pursuits (Eisenhardt, 1989; Heavey, Simsek, Roche, & Kelly, 2009). Despite SDC's merit in new product development, however, a large-sample empirical test of how SDC links to new product performance is still missing. This study contributes to the literature by positing and testing an integral model of SDC in new product development.

1.3 Methodologies used and data collection

The three studies in this dissertation represent different research questions that require different statistical methods and data sets. Study 1 poses a general question about ambidexterity,

regardless of specific contexts. For this study, a cross-sectional survey is suitable. Study 2, however, attempts to develop an understanding of standard participation. This demands data for the specific context of standard setting. Study 3 requires a finer-grained data set as it aims to study the effect of strategic decision making on new product development. Table 1.1 summarizes the data collection method, data characteristics, and statistical methods employed.

Table 1.1 Data collection method, sample size, and context

Study	Data source	Sample size	Context	Statistical methods
1	Self-collected survey data	300 firms	Chinese high-tech firms	Seemingly unrelated regression (SUR)
2	Public data from SSOs, NBER, and COMPUSTAT	270 firms	Global ICT sectors	A combination of panel negative binomial, panel GEE, and panel OLS
3	Self-collected survey data	149 projects	American manufacturing business	Hierarchical moderated OLS

1.3 Overview of the studies included in this dissertation

These three studies as a whole offer a more nuanced view of how firms can manage different organizational learning processes for superior innovation performance. In what follows, I will discuss briefly the research objectives, method, and main contributions of the three studies included in the dissertation.

Learning to Innovate: How Does Ambidextrous Learning Matter to Radical and Incremental Innovation Capabilities? (with Keld Laursen & Kwaku Atuahene-Gima) investigates the effects of ambidextrous learning on the radical and incremental innovation capabilities of the firm. The novelty of this study is both theoretical and empirical. We propose and test a new framework for understanding incremental and radical innovation, i.e.,

technological discoveries (captured by synergy of ambidexterity) for incremental innovation development and overcoming organizational inertia (captured by balance of ambidexterity) for radical innovation creation. Our empirical approach involves an interview and questionnaire survey with Chinese high-tech firms and multivariate analysis with seemingly unrelated regression (SUR). We highlight the importance of balancing different types of learning for the development of radical innovation, which has not received adequate attention in the literature.

Standard Gold Rush? A Longitudinal Study of Standard-Setting Participation and Innovation Performance examines how learning through knowledge sharing affects firms' innovation performance. The empirical context of this study is standard setting, a context in which large numbers of innovative technologies have been co-developed. For the empirical analysis, I construct a longitudinal data set tracing the standard-setting activities and patenting activities of public ICT firms for a 10-year period. I find that standard participation 1) has an inverted-U relationship with the patent rate and 2) positively relates to share of exploitative patenting. I also find that the effect of standard participation on the innovation rate is contingent on firms' R&D intensity. While having one's technology included in an industry standard may result in a favorable competitive environment and in substantial royalty revenue, this paper warns that reliance on standard setting might have detrimental effects on firms' innovation performance.

Understanding Strategic Decision Comprehensiveness – Performance Relationship in New Product Development (with Kwaku Atuahene-Gima & Haiyang Li) refines the relationship between strategic decision comprehensiveness (SDC) and performance. Arguing that SDC is especially valuable for new product development, we ask how and when SDC leads to new product performance. We develop an integrative model of the strategic decision process, which

includes decision quality as the process outcome and performance as the economic outcome. For empirical testing, we conduct a questionnaire survey with a list of manufacturing firms in the United States. Using hierarchical moderated regression, we find that SDC leads to better decision quality, particularly when competitive uncertainty is low and when customer demand sophistication is high. We also find that decision quality leads to better new product performance when the implementation speed is faster and the implementation is less complex.

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LEARNING TO INNOVATE: HOW DOES AMBIDEXTERITY MATTER FOR RADICAL AND INCREMENTAL INNOVATION CAPABILITIES?

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Abstract

The notion that ambidextrous learning—involving both exploration and exploitation—will improve firm performance, has become prominent in academia and practice. While arguing that innovation capabilities are central to the ambidexterity hypothesis, we investigate how the two dimensions of ambidextrous learning (combined and balanced) affect firms' incremental and radical innovation capabilities. Based on organizational learning theory, we develop theoretical arguments underpinning the idea that the combined dimension of ambidexterity drives incremental innovation capability while the balance dimension of ambidexterity positively influences radical innovation capability. We base our empirical analysis on a survey of high-tech firms in China. We find support for our theoretical arguments.

INTRODUCTION

To manage evolutionary and revolutionary change, firms need to engage in ambidextrous learning: exploitation extends current knowledge enabling greater efficiency and reliability; exploration allows for the development of new knowledge to increase novelty and flexibility (Atuahene-Gima, 2005; March, 1991; O'Reilly & Tushman, 2004). For instance, Huawei's and Ericsson's successful introduction in 2009 of the worlds' first LTE (4G) mobile broadband commercial network in Oslo, Norway, has been said to be a result of explorative and exploitative learning processes (Ricknäs, 2009). Following Tushman and O'Reilly (1996), ambidexterity can be defined as the simultaneous pursuit of exploration and exploitation, and has been hypothesized to improve firm performance and survival (e.g., Cao, Gedajlovic, & Zhang, 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; Lin, Yang, & Demirkan, 2007; Rothaermel & Alexandre, 2008). Although knowledge about the phenomenon of ambidexterity has increased greatly as a result of Tushman and O'Reilly's contribution and subsequent academic work, this literature has two important limitations.

The first is related to the fundamental argument of the ambidexterity hypothesis that, as suggested by Tushman and O'Reilly (1996), ambidextrous firms achieve competitive advantage based on continuous innovation—both incremental and radical (also, see He & Wong, 2004). However, there is little evidence on the role played by ambidexterity in building firms' innovation capabilities. An exceptions is Tushman et al. (2010), which studies the relationship between organizational design and innovation streams, and finds that ambidextrous organizational design is associated with better innovation outcomes. However, this is a multi-case study and the results, therefore, are only indicative. Relatedly, He and Wong (2004) acknowledge the significant relevance of innovation outcomes. However, while they measure

innovation outcomes as the intensity of product and process innovation, they are unable to establish an empirical link between any two measures of ambidexterity and innovation.

The second and related limitation concerns how ambidexterity and innovation should be linked. Interestingly, although the link between ambidexterity and innovation has been examined explicitly to only a limited degree, the ambidexterity literature assumes an implicit relationship (Cao et al., 2009; Jansen, Van Den Bosch, & Volberda, 2006; Lin et al., 2007). In particular, while arguing that exploration is related to the development of radical innovation, and exploitation to the development of incremental innovation, the literature assumes that ambidextrous firms can pursue different types of innovation effectively, and operationalizes ambidexterity in terms of both exploitative/explorative learning (e.g., Lavie, Stettner, & Tushman, 2010; Rothaermel & Alexandre, 2008) and incremental/radical innovation (Cao et al., 2009; He & Wong, 2004; Jansen, Simsek, & Cao, 2012).

This operationalization raises some concerns. In keeping with March (1991), He and Wong (2004: 485) state explicitly that "exploration and exploitation should be used with reference to a firm's ex-ante strategic objectives in pursuing innovation, whereas the radical versus incremental innovation is often used in an ex-post outcome sense". Treating exploitation and exploration as equivalent to incremental innovation and radical innovation overlooks other influencing links. For example, exploitation might affect firms' radical innovation capability by promoting a competency trap (Leonard-Barton, 1992) or reduced absorptive capacity (Cohen & Levinthal, 1990); exploration might have an impact on incremental innovation capability through the contributions of multiple sources to the "fine-tuning" of new products (Laursen & Salter, 2006) and allowing the firm to keep "abreast of development for improving current operations" (Dewar & Dutton, 1986: 1424). Thus, the link between ambidexterity and innovation may be more

complex than previous research would suggest. Certainly, the ambidexterity literature highlights the interaction effect between exploration and exploitation on performance outcomes (e.g., Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004). Several scholars have argued that exploitation and exploration are non-substitutable and interdependent constructs (see for instance, Cao et al., 2009), and provide strong empirical evidence that their co-existence means they should be treated as part of an integral concept, i.e., ambidexterity.

We seek to address the above limitations of the extant literature. Our point of departure is that it would be useful to distinguish between and explicitly examine the links between ambidexterity (learning processes) and firms' innovation capabilities (learning outcomes). Given that ambidexterity is regarded as an emerging research paradigm in organizational theory (Raisch & Birkinshaw, 2008) and is part of the many prescriptions for increased firm performance, improvement, and survival (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996), explicit investigation of its impacts on the incremental and radical innovation capabilities of firms would be beneficial. In distinguishing between two dimensions of ambidexterity, i.e. combined and balance (following Cao et al., 2009), the present study links ambidexterity to firms' incremental and radical innovation capabilities. To the best of our knowledge, this is the first study to attempt this. Our central argument is that synergy between exploitation and exploration (exploitation and exploration *combined*) facilitates technological opportunity discovery for the development of incremental innovation, and a balance between them reduces organizational inertia allowing the development of radical innovation. Indeed, we suggest that He and Wong's (2004) failure to establish an empirical link between ambidexterity and innovation might be explained by the fact that the effect of ambidexterity depends on the type of ambidexterity vis-à-vis the type of

innovation capability (incremental or radical). Using survey data from a sample of high technology firms located in China, we find overall support for our theory and hypotheses.

This study makes novel theoretical and empirical contributions to the ambidexterity literature. First, the ambidexterity literature generally takes a contingency approach to the ambidexterity-firm performance link in order to understand the boundary conditions of the ambidexterity hypothesis (e.g., Cao et al., 2009; Lin et al., 2007). Although the contingency approach has provided rich insights, it has a major shortcoming. Investment in ambidexterity *per se* may not have a profound effect on firm performance, unless this investment is translated into an innovation advantage (Tushman & O'Reilly, 1996). In considering a direct ambidexterity-firm performance effect, the contingency approach fails accurately to estimate the effects of ambidexterity. In this paper, we theoretically and empirically link ambidexterity directly with innovation outcomes, i.e. we show the effect of ambidexterity on firm innovation. In our view, an approach that links ambidexterity with innovation outcome measures reduces confounding effects, and potentially offers a more fine-grained account of the effects of ambidexterity.

Second, departing from the traditional dual structure approach to ambidexterity, recent advances in the ambidexterity literature argue that interplay between exploitation and exploration is essential for superior performance outcomes (Gibson & Birkinshaw, 2004). Taylor and Helfat (2009) point out that "linkages (between exploration and exploitation) are critical but overlooked elements of organizational ambidexterity". Focusing on the interplay between exploitation and exploration, this study advances conceptualizations of the ambidexterity construct and related theory. Although the prior literature distinguishes the two dimensions of ambidexterity empirically, to our knowledge, this is the first study to theoretically relate the combined dimension of ambidexterity to technological discovery, and the balance dimension of

ambidexterity to organizational inertia. Furthermore, we provide an empirical test of the new theory explaining incremental and radical innovation outcomes by firms.

THEORETICAL BACKGROUD

Ambidexterity: Concepts and Dimensions

March (1991) describes variation-seeking, risk-taking, and experimentation-oriented learning activities as exploration, and variety-reducing and efficiency-oriented learning activities as exploitation. Applying March's (1991) view to the domain of product innovation, we define exploitative learning (exploitation) as the use of and refinements to existing product development knowledge and skills, and explorative learning (exploration) as the search for and pursuit of completely new knowledge and skills for product development (see also, Benner & Tushman, 2003). March (1991) argues that to survive environmental changes, firms need to balance exploitation and exploration. Too much exploitation results in inertia; too much exploration results in reduced efficiency (Levinthal & March, 1993; March, 1991). Also, exploitation and exploration are associated with inconsistent and sometimes competing organizational logics: while exploitation is associated with efficiency, refinement, and focus, exploration is based on experimentation, flexibility, and divergent thinking (March, 1991). Perhaps paradoxically, however, the firm's long-term survival depends on its capacity simultaneously to pursue exploration and exploitation (Raisch, Birkinshaw, Probst, & Tushman, 2009), which is defined as firm ambidexterity.

Fundamental to ambidextrous learning (ambidexterity) is the ability to manage strategic contradiction, which shifts managerial attention away from discrete choice processes ("either/or") to paradoxical ("both/and") thinking (Smith & Tushman, 2005). Smith and Tushman (2005) consider the management of strategic contradiction to be associated with two distinct cognitive

processes—differentiation and integration. Differentiation involves categorizing the differences between exploitation and exploration such that resources can be allocated clearly to each activity. Integration involves identifying the opportunities offered by the linkages and synergies between exploitation and exploration. Thus, ambidexterity can be considered along the two dimensions of differentiation and integration. For example, Gupta et al. (2006) propose that the relationship between exploitation and exploration can be both competing (each end of a continuum) and complementary (orthogonal). On the one hand, exploitation and exploration are competing over scarce resources and in conflicts over organizational routines (March, 1991). On the other hand, exploitation and exploration are complementary because they can be mutually supporting (Katila & Ahuja, 2002). From an empirical perspective, Cao et al. (2009) posit that ambidexterity encompasses two dimensions: the difference between exploitation and exploration that captures the relative balance between the two, and the product of exploitation and exploration to reflect their combined or synergy effect. Cao et al. (2009) term these dimensions "the balance dimension of ambidexterity" (BD) and "the combined dimension of ambidexterity" (CD).

Inspired by these authors, in this paper we consider both dimensions and disentangle their different effects in order to examine how ambidexterity matters for the firm's innovation capabilities. The first dimension (BD) reflects the relative magnitudes of exploitation and exploration. Achieving balance of ambidexterity involves recognizing, articulating, and exploiting the differences between exploitation and exploration. Balanced ambidexterity suggests that the cognitive commitment to exploitation or exploration is reduced, and that firms are able to develop complex behaviors which allow exploitation and exploration activities to co-evolve within the organization. Thus, achieving a balance of ambidexterity will effectively reduce organizational inertia because it prevents the firms from engaging in over-exploitation or over-

exploration.

The second dimension of ambidexterity (CD) captures the potential cross-fertilization effect between exploitation and exploration. Whereas balance of ambidexterity involves differentiating between exploitation and exploration, combined ambidexterity shifts managerial attention to their mutual benefits. Combined ambidexterity reflects an opportunistic framing that shifts attention from the threats of and competition between exploitation and exploration, to their potential synergies. Central to combined ambidexterity is the idea that exploitation and exploration might be mutually supportive (synergistic) based on shared resources and knowledge (Cao et al., 2009). For instance, Gilbert (2005) demonstrates how the online business USA TODAY benefited from shared editorial content across platforms. Indeed, Taylor and Helfat (2009) argue that the firm's ability to create synergies between exploitation and exploration is a critical component of ambidexterity.

Incremental and Radical Innovation Capabilities

In dynamic environments, sustained organizational performance is rooted in the firm's capabilities to engage in incremental and radical innovation simultaneously (Christensen, 1997). Incremental innovation is an improved product and/or product line expansion that involves small changes to the technology and minor deviations from the firm's existing product-market experience. Radical product innovation involves a new product that disrupts an existing technological trajectory and involves major transformations compared to the existing product (Atuahene-Gima, 2005; Gatignon, Tushman, Smith, & Anderson, 2002; Subramaniam & Youndt, 2005). Incremental innovation capabilities offer short-term efficiencies by allowing the firm to capture the ongoing benefits from existing operations; radical innovation capabilities facilitate long-term effectiveness by moving the firm onto new technological trajectories for adaptation

and change (Smith & Tushman, 2005; Tushman & O'Reilly, 1996).

Firms vary in their capabilities to generate incremental and radical innovations (Subramaniam & Youndt, 2005). For example, in the late 1960s, Goodyear became trapped into producing only bias-ply tires despite efforts to develop radial tires (Sull, Tedlow, & Rosenbloom, 1997); while in the optical business, Ciba Vision was famous for radical innovations such as Visudyne, in totally new markets, and its ability to make continuous incremental improvements to its existing hard contact lenses, which increased the price/performance frontiers (Tushman & O'Reilly, 1997). Thus, it is important for firms to learn how to accumulate incremental and/or radical innovation capabilities. Building on the organizational learning literature, prior studies on the organizational antecedents associated with multiple innovation types highlight the relevance of March's (1991) distinction between exploitation and exploration. Assuming that innovation is a function of technological opportunities, this literature generally links exploitation with incremental innovation, and exploration with radical innovation. However, the empirical work yields mixed results. For example, Laursen and Salter (2006) in a sample of U.K. firms finds evidence that is consistent with the idea that exploration enhances the development of both incremental and radical innovation, while exploitation supports radical innovation but has no effect on incremental innovation, whereas Dewar and Dutton (1986) report exploitation as driving both types of innovation, but find no effects of exploration.

Our argument advances both of these perspectives. Specifically, we argue that the development of incremental innovation is driven by the discovery of technologies along a trajectory, while the development of radical innovation is enabled by overcoming organizational inertia. At the heart of this argument is the distinction between how different types of innovation capabilities draw on organizational knowledge:

> incremental innovative capabilities draw upon reinforced prevailing knowledge, with consequent innovations taking advantage of and improving upon prevailing knowledge, whereas radical innovative capabilities draw upon transformed prevailing knowledge, with innovations making prevailing knowledge obsolete and "morphing" old knowledge into something significant new. (Subramaniam & Youndt, 2005: 452)

We submit that the pursuit of incremental innovation is technologically challenging, but not organizationally challenging to an important degree. We suggest that the capability to develop a continuous stream of incremental innovations requires the firm to search for and to discover new technological opportunities along an established trajectory (Dosi, 1982). Since incremental innovation is typically aligned with the firm's prevailing knowledge and existing innovation trajectory (Subramaniam & Youndt, 2005), we suggest that the development of incremental innovation is unlikely to face major opposition within the firm since it is unlikely to challenge any of the organization's members.

The obstacle to radical innovation is most often not technological in nature. Advanced corporations are generally able to develop and absorb radically new technologies but often find it difficult to overcome organizational inertia, and ultimately may forego the potential offered by radical innovation (Hill & Rothaermel, 2003; Smith & Tushman, 2005). Thus, we argue that the development of radical innovation is more organizationally challenging, i.e., radical innovation capabilities are rooted in the firms' abilities to attenuate inertial forces that steer firms towards obsolescence. In the context of this study, we highlight two sources of organizational inertia,[1] over-exploitation and over-exploration (Liu, 2006; Smith & Tushman, 2005). It has been found that in established firms, exploitation-driven inertia traps the firm within existing competency,

[1] In this paper, we do not differentiate between organizational inertia and competency traps.

reducing its innovativeness (Levinthal & March, 1993; March, 1991). In order for firms to escape exploitation-driven competency traps, it is important for them to engage in exploration (March, 1991). However, too much exploration can also promote organizational inertia. Over-exploration will exhaust valuable firm resources on "too many underdeveloped ideas and too little distinctive competence" (Levinthal & March, 1993: 105). Although significant amounts of knowledge may be obtained through excess exploration, it is never exploited to enhance the firm's innovation capabilities. As a result, firms that engage in over-exploration find that forces of inertia trap them into ceaseless exploration, underutilization of knowledge, and incapability to innovate (Lewin, Long, & Carrol, 1999). Sull (1999) describes this pattern of behavior as "active inertia".

Our view of incremental and radical innovation capabilities is consistent with the innovation literature. For example, Henderson and Clark (1990) documents how, on the one hand firms are challenged by architectural innovation—strongly related to how the firm organizes—despite its technological simplicity, and on the other hand are capable of hosting generational innovation regardless of its technological complexity. Similarly, Hill and Rothaermel (2003) emphasize how organizational inertia prevents incumbent firms from embracing radical innovation, while Tripsas (1997) documents how investment in technological discovery through internal R&D and external knowledge acquisition helped the Mergenthaler Linotype Company to make incremental improvements to the Hot Metal typesetter.

HYPOTHESES

Dimensions of Ambidexterity and the Firm's Incremental Innovation Capabilities

As noted above, incremental innovation capabilities are rooted in the firm's ability to discover new technologies. We submit that there is a strong positive relation between a firm's incremental

innovation capability and the combined dimension of ambidexterity. The idea is that (increased) investment in exploration activity will increase the benefits of exploitation activities, and (increased) investment in exploitation activity will increase the benefits of exploration activities to discover new technologies. In this context, and departing from the premise that exploitation (depth) enhances innovation effectiveness while exploration (scope) enriches innovation possibilities, Katila and Ahuja (2002) argue that exploitation and exploration are mutually beneficial. Exploitation facilitates assimilation and the further development of new knowledge generated through the process of exploration due to absorptive capacity, and exploration increases the likelihood of creating new combinations of heterogeneous knowledge. In sum, the synergy between exploitation and exploration increases the efficiency and effectiveness of knowledge creation in the firm, which increases the likelihood of technological discoveries, and hence the development of incremental innovation. Thus, we posit that:

Hypothesis 1a. The combined dimension of ambidexterity contributes to the firm's incremental innovation capability.

However, we expect the firm's incremental innovation capability to benefit more from combined ambidextrous learning than from balance of ambidextrous learning. This hypothesis requires us to establish that there is either no or a negative relationship between incremental innovation and balance of ambidexterity. The logic is as follows: Above we argued that balance of ambidexterity captures the level of organizational inertia: the more balanced, the less the organizational inertia. It is well-understood that any change to an organization that has major implications for that organization, typically will face strong internal resistance unless strong measures are put in place to alleviate this resistance (Battilana & Casciaro, 2013; Coch & French, 1948). One important source of resistance is activities pertaining to product and process

innovations (Dougherty & Heller, 1994). Most organizations have the capability for incremental innovation because incremental innovation by definition is aligned to the firm's prevailing knowledge (Subramaniam & Youndt, 2005) and related business model. Incremental innovation is not likely to challenge the firm's prevailing practices or established structures. Thus, activities related to incremental innovation are unlikely to create noticeable organizational resistance. We have argued that the balance dimension of ambidexterity affects the firm's innovation capability by reducing organizational inertia, thus the balance dimension of ambidexterity is unlikely to have an effect on incremental innovation. Factoring in the arguments related to both combined and balanced ambidexterity, we hypothesize that:

Hypothesis 1b. The combined dimension of ambidexterity contributes more than the balance dimension of ambidexterity to the firm's incremental innovation capability.

Dimensions of Ambidexterity and Radical Firm Innovation Capabilities

As stated above, we argue that the firm's radical innovation capability is positively related to balance ambidextrous learning based on the premise that radical innovation depends on the firm's ability to overcome organizational inertia. Certainly, radical innovation capability depends on the firm's ability to transform its existing knowledge and disrupt the dominant technological trajectory (Subramaniam & Youndt, 2005). However, discovery of radical technology does not guarantee development of radical innovation—organizational inertia prevents the firm from exploiting even radical technology that has been developed internally (Hill & Rothaermel, 2003). Organizational inertia can retard the development of radical innovations when a new business model is required (Chesbrough & Rosenbloom, 2002); when new customer segments with different preferences emerge (Christensen & Bower, 1996); and when the reconfiguration of existing technologies is needed (Henderson & Clark, 1990). As already mentioned, we assume

that firms that perform predominantly exploratory or exploitative learning can be characterized as having strong organizational inertia, while firms that balance their exploratory and exploitative learning can overcome any organizational inertia. Balance of ambidexterity allows managers to avoid cognitive commitment to the past, and reduce reliance on the previously established ways of solving problems and particular learning modes. In sum, we posit that balance of ambidexterity reflects a lack of organizational inertia—the more balanced exploitation and exploration, the less organizational inertia will be present within at the firm, and hence the stronger will be the firm's capabilities for radical innovation. Accordingly, we hypothesize:

Hypothesis 2a. The balance dimension of ambidexterity benefits the firm's radical innovation capability.

Nevertheless, in addition to our conjecture of a positive relationship between the balance dimension of ambidexterity and the firm's radical innovation capability, we expect the firm's radical innovation capability to benefit more from balanced than combined ambidextrous learning. This hypothesis is based on the arguments in favor of Hypothesis 2a, and on the idea that there should be no or a negative relationship between radical innovation and combined ambidextrous learning. In the latter case, the effect of combined ambidexterity on radical innovation capabilities is not obvious. Emphasizing that the interaction between exploitation and exploration will increase the distinctive benefits of both exploitation and exploration, combined ambidexterity reflects an opportunistic framing and promotes cooperation between exploitation and exploration. On the one hand, the interaction between exploitation and exploration activities increases the likelihood of technological discoveries; on the other hand, the interaction between exploitation and exploration increases the interdependence between exploitation and exploration and fosters organizational inertia. Increased interdependence constrains the firm's ability to

disrupt the existing technological trajectory because change in one activity might require concomitant changes to other activities (Sorenson, 2003). Moreover, Chandy and Tellis (1998) argue that due to the increased interdependence between exploration and exploitation, an emphasis on combined ambidexterity decreases firms' willingness to cannibalize existing technology, and reduces firms' radical innovation capabilities. In other words, synergies between exploitation and exploration can reinforce organizational inertia, making development of radical innovation less likely. Considering the arguments related to both combined and balanced ambidexterity, we hypothesize that:

Hypothesis 2b. The balance dimension of ambidexterity benefits the firm's radical innovation capability more than the combined dimension of ambidexterity.

RESEARCH METHODS

Sample and Data Collection

To test our propositions, we collected data from high technology firms in China. The Chinese market environment is complex and dynamic with new products from incremental and radical innovation being introduced to the market at an unprecedented pace. To survive and to maintain competitive advantage, firms need to exploit existing capabilities and develop new ones that are specific to the Chinese market (Zhou & Wu, 2010). At the same time, the high degree of uncertainty in the task environment means there is substantial variability in Chinese high technology firms' degrees of engagement in exploitation and exploration, which in turn produces wide variations in the levels of ambidexterity (Cao et al., 2009).

The sample includes 568 firms selected randomly from a consulting firm's directory of 2,500 high technology firms. We followed the traditional double-translation method to develop our research instrument. Translation accuracy was insured by it being produced first in English,

then translated into Chinese and back into English. We pre-tested the instrument in interviews with 17 managers with at least three years of business experience in China, to ensure face validity of the constructs and clarity of the survey questions. The data were collected on site and the instrument was delivered to informants personally by a trained interviewer, who collected them after completion. To ensure the integrity of the response data, informants were contacted by phone to confirm that they had completed the questionnaire. We offered to provide a summary of the research results to informants, to encourage conscientiousness in providing data which would make the research findings meaningful.

Our data collection strategy followed the recommendations in Podsakoff et al. (2003) to reduce common method variance. Primary data on different constructs were collected from different informants. The data for all the variables except the dependent variables were provided by the first respondents; these included predominantly marketing managers (97%) and chief executive officers (CEOs) (3%). Their mean industry experience was 11.22 years and mean knowledge level was 6.2 (1 - "not at all knowledgeable", 7 - "extremely knowledgeable"). Our first respondents nominated a second knowledgeable informant to provide data on the dependent variable. The informants were: CEOs (45%), business development managers (35%), marketing managers (4%), and R&D managers (16%). The mean industry experience of these informants was 8.99 years and mean knowledge level was 5.1 (1 - "not at all knowledgeable", 7 -"extremely knowledgeable"). We assured informants of anonymity, that there were no right or wrong answers, and that "don't know" was a legitimate option; this enhanced the quality of the data obtained from informants.

The final sample consists of 204 firms (408 questionnaires) and a response rate of 35.9 percent, which compares well with response rates reported for similar surveys (e.g. , De Luca &

Atuahene-Gima, 2007; Zhou, Li, Zhou, & Su, 2008). Respondents included firms from the following sectors: 27 percent electronics and information technology, 20 percent computer and software, 16 percent optical mechanical and electrical products, 13 percent new energy and materials, 11 percent chemical/pharmaceutical/biotech, 11 percent telecommunications, and 2 percent "other industries", such as scientific instruments. Since we conducted on-site data collection, testing response bias by comparing early and late respondents does not apply. We compared a sample of 150 participating firms with a sample of non-participating firms for which we had data on R&D expenses and the number of employees. Comparing the mean of R&D investments and number of employees shows no significant differences between the two groups.

Common Method Bias

Our research design involves cross-sectional data, which tend to be vulnerable to common method bias. We alleviated potential concerns first by using different sources for the independent and dependent variables, and second by examining a single-factor model in which all items were loaded onto one factor to check for presence of common method bias (Podsakoff et al., 2003). The single factor model shows poor fit (comparative fit index CFI=.344, root mean squared error of approximation RMSEA=.146), suggesting that common method bias is unlikely to be a major concern. Finally, we tested for several interaction effects that could not be explained by common method bias because our informants were unlikely to guess the complex relationships involved (Aiken & West, 1991).

Measures

Dependent variables. Following Subramaniam and Youndt (2005), we captured *incremental innovation capability* by asking managers to assess their firms' capability to reinforce and extend their current expertise and product lines in the previous three years (see

Table 1 below for a detailed description of the constructs and items used in this study). Firms' *radical innovation capability* is captured by responses to the question asking managers to assess their firms' capability to generate innovation that had rendered the current product/service lines obsolete in the previous three years. Our design of a three-year time frame is supported by two practical considerations. Firstly, Miller et al. (1997) suggest restricting the recall time frame to three years or less to minimize the burden on respondents related to recalling data. Secondly, He and Wong (2004) argue that a three-year period is appropriate for studying innovation in dynamic Asian economies where most firms carry out innovation projects with short project duration and payback periods.

Independent variables. As already argued, ambidexterity is seen as an integrative exploration and exploitation construct. In line with the literature we measure ambidexterity based on the measures of its underlying exploration and exploitation dimensions. To measure *exploitation*, we followed Atuahene-Gima (2005) to capture the extent to which learning activities in the previous three years were focused on the acquisition of information in the neighborhood of the firm's market and product knowledge base, for the purpose of improving productivity and efficiency. To measure *exploration*, we used the five-item list in Atuahene-Gima (2005), which asks respondents to indicate the extent to which, in the previous three years, the firm had learned skills unrelated to its current market and product experience and knowledge, for the purposes of experimentation. Using a 7 point scale, we found that the average firm conducts 4.87 exploitation (s.d.=0.88) and 4.69 exploration (s.d.=0.89) activities, providing further evidence of the ambidextrous orientation of Chinese high technology firms (see also, Cao et al., 2009, for similar findings).

Recall that the combined dimension of ambidexterity (*combined ambidexterity*) is defined as the interaction between exploration and exploitation; we measure it as the product of exploitation and exploration. As defined earlier, the balance dimension of ambidexterity (*balance of ambidexterity*) refers to the relative extents of exploration and exploitation. We follow previous studies and measure balance of ambidexterity as the absolute difference between exploration and exploitation (Cao et al., 2009; He & Wong, 2004). To facilitate interpretation, we follow Cao et al. (2009) and reverse this measure by subtracting the difference score from 7 such that a higher value indicates a better balance between exploration and exploitation.

Control variables. In addition to the main explanatory variables, innovation capability can be affected by several other firm-specific and environmental factors. At firm level, we control for *organizational slack, inter-functional coordination, intelligence failure reward system, willingness to cannibalize, firm size,* and *R&D intensity*, all of which it is believed can impact on the firm's innovation activities (Chandy & Tellis, 1998; Chattopadhyay, Glick, & Huber, 2001; He & Wong, 2004). The measure of organizational slack is borrowed from De Luca and Atuahene-Gima (2007) and reflects the availability of excess resources to fund new initiatives at short notice. Inter-functional coordination is measured by six items from Li and Calantone (1998) and Zahra and Nielsen (2002) and captures the extent of tight links among functions. Intelligence failure reflects concern for immediate success or failure of creative and learning-oriented activities. Given high propensity of failure in creative activities, an intelligence failure reward system can provide an incentive for engaging in these activities. We use three items from Joshi and Sharma (2004) to measure the degree to which firms use an intelligence failure reward system, which captures the firm's incentive to learn from mistakes. Willingness to cannibalize is measured by three items adapted from Chandy and Tellis (1998), and firm performance is the

firm's performance relative to that of its main competitor in six areas including profit growth and return on assets. Firm size is measured by the logarithm of the number of full time employees. R&D intensity was measured by asking managers to specify the percentage of R&D to sales in a particular year. Two dummy variables are included to indicate *ownership* and *industry*. Ownership takes the value 1 if the firm is state-owned, and zero otherwise. Finally, to capture environmental dynamics, we control for *technology, customer* and *competitor uncertainties*. Technology uncertainties are measured by four items developed by Jaworski and Kohli (1993), while customer and competitor uncertainties are taken from Atuahene-Gima and Li (2002).

Validation of Measures

We refine the measurements using STATA 12. First, we ran exploratory factor analysis for each set of focal constructs, on each of the groups of informants; this resulted in the expected factor solutions. Second, we submitted all the items for confirmatory factor analysis (CFA) to assess the validity of the latent constructs. To ensure acceptable parameter estimate-to-observation ratios, we group measures of theoretically related constructs and run two sub-models. This approach is well established in the literature (e.g., Li & Atuahene-Gima, 2001; Moorman & Miner, 1997). The first CFA groups items measuring exploration, exploitation, incremental innovation capability, and radical innovation capability. The second CFA analyzes organizational slack, inter-functional coordination, willingness to cannibalize, technology uncertainty, customer uncertainty, and competitor uncertainty measures.

The fit indices presented in the Appendix indicate that in both models data fit is good. All item standardized loadings for each construct are significant (p=.000) and strong (.58 - .89) with no major cross-loadings emerging, which supports the unidimensionality of the constructs. The R-squared value (.34 to .79) is well above the usual threshold of .20 (Hair, Anderson, Tatham, &

Black, 1995), providing clear support for linearity. To assess convergent validity, we calculated Cronbach's Alpha coefficient for each set of constructs (.73-.87), which were above the .70 threshold for the test of reliability. We calculated composite reliability (.76 - .88) using the procedures in Fornell and Larcker (1981), and calculated average variance extracted (AVE - .51-.71)) using the procedures in Anderson and Gerbing (1982). Comparing composite reliability with the recommended threshold of .70, and AVE with the recommended threshold of .50, we can conclude that the models pass the tests and demonstrate good convergent validities for these constructs. Finally, we tested for discriminant validity using the AVE method recommended by Fornell and Larcker (1981): for each construct the square root of its AVE is greater than the highest correlation with any other construct. All constructs pass the discriminant validity test. We also performed a series of chi-square difference tests for all constructs in pairs to determine whether the unconstrained model is significantly better than the constrained model. All the chi-square differences are highly significant, confirming discriminant validity.

Insert Table 1 about here

ANALYSIS AND RESULTS

Table 2 presents the descriptive statistics and the bivariate correlation matrix. The variables reflecting the hypothesized effects are not highly correlated with each other, or with the control variables. It is noteworthy that the correlation between combined and balance of ambidexterity is found to be significant but low (r = 0.19), suggesting two separate constructs. Even though no inter-factor correlation is above the 0.65 threshold, we note that the correlation between exploration and exploitation is high (0.62). A robustness check involving deletion of the insignificant exploitation variable and multicollinearity diagnoses (see below for details) both indicate that the results are strong and unaffected by the high correlation between exploration and exploitation.

Insert Table 2 about here

Ordinary least squares (OLS) regressions of ambidextrous learning on incremental and radical innovation capabilities respectively could be employed to detect the relationship between ambidextrous learning and innovation capabilities. Applying a single-equation OLS approach, however, assumes that the two dependent variables are independent of one another, which is unlikely to be the case here since incremental and radical innovation capabilities are likely to be positively related to one another. To overcome the issue of correlation of error terms between the two equations, the standard approach would be to employ seemingly unrelated regression (SUR), which estimates several individual relationships that are linked by the fact that their error terms are correlated across equations. Zellner (1962) shows that joint estimation of these equations using SUR is more efficient than separate OLS estimations. Thus, we use SUR analysis to test our hypotheses. We also perform a Breusch-Pagan test of independence of the residuals to asses

our choice of econometric model. The test statistic supports our conjecture regarding correlated error terms (chi2(1)=14.80, p=0.00).

The analysis consists of several steps. In step 1, we include all the control variables, including exploitation and exploration, in the baseline models (Model 1 and Model 5). In step 2, we add combined ambidexterity to the baseline models (Model 2 and Model 6). In step 3, we add balance of ambidexterity to the models obtained from step 2 (Model 3 and Model 7). Model 4 and Model 8 are the full models including combined and balance of ambidexterity. We conducted collinearity diagnostics by calculating variance inflation factors (VIFs) for each of the regression variables. The maximum VIF is 2.26, which is well below the rule-of-thumb cutoff of 10 (Cohen, Cohen, West, & Aiken, 2003). The result suggests that our estimations are unlikely to be affected by multicollinearity problems.

Tables 3 and 4 present the results of the regression analysis for the hypotheses. Model 1 and Model 5 are the baseline models with control variables only. The firm-internal factors are the main drivers of both incremental and radical innovation capabilities. Failure reward plays a different role in radical and incremental innovation capabilities: it decreases incremental innovation capability (p<0.01) and enhances radical innovation capability (p<0.01). The availability of organizational slack is important for enhancing radical innovation capability (p<0.01) while the tight functional link hinders the development of radical innovation (p<0.01). We observe that the two learning variables, exploration (p<0.01) and exploration (n.s.) both have positive signs for affecting incremental innovation capabilities, confirming our proposition that technology opportunities from both exploration and exploitation may be sources of incremental innovation. For radical innovation capability, both exploration (p<0.10) and exploitation (n.s.) are negative, suggesting that either exploration or exploitation on their own do not have a

positive impact on radical innovation capability. Again, this result supports our argument that technological discoveries generated through exploitation or exploration are not important drivers of firms' radical innovation capability.

Insert Table 3 about here

Model 2 investigates H1a stating that the combined dimension of ambidexterity benefits a firm's incremental innovation capability. In support of H1a, Model 2 shows that combined ambidexterity has a positive effect on incremental innovation capability. Model 3 adds balance of ambidexterity. We focus on Model 4 which includes both combined and balance of ambidexterity, to test H1b stating that combined ambidexterity benefits a firm's incremental innovation capability more than balance of ambidexterity. First, adding the combined and balance dimensions of ambidexterity to the model increases the adjusted R^2 from 27.0 percent to 30.9 percent (ΔR^2 =3.9%). Second, combined ambidexterity has a positive effect on incremental innovation capability (p<0.01) while balance of ambidexterity has a negative effect (p<0.01). As predicted by H1b, the development of incremental innovation benefits from the combined dimension of ambidexterity more than from the balance dimension of ambidexterity.

Models 5–8 investigate the link between ambidexterity and radical innovation capability. In support of H1a, model 6 shows a positive effect (p<0.05) of the balance dimension of ambidexterity on radical innovation capability. Meanwhile, Model 7 shows a positive but insignificant effect of combined ambidexterity on radical innovation capability. Model 8 examines H2b that the balance of ambidexterity benefits a firm's radical innovation capability more than combined ambidexterity. Adding combined and balance of ambidexterity to the model increases the adjusted R^2 from 30.7 percent to 32.4 percent (ΔR^2 =1.7 percent). Both the combined and balance dimensions of ambidexterity have positive signs, but only balance of

ambidexterity significantly and positively affects radical innovation capability ($p<0.05$). The size effect of balance of ambidexterity is 19 times greater than that of combined ambidexterity. Thus, we find support for H2b asserting that the development of radical innovation benefits more from the balance dimension of ambidexterity than from the combined dimension of ambidexterity.

Insert Table 3 about here

Additional Analyses

We explored the robustness of the results presented above in several additional analyses. First, ambidextrous learning is a choice variable since firms decide whether and how to engage in ambidextrous learning. It introduces endogeneity concerns to our models. Specifically, we could argue that the correlation between ambidexterity and innovation capabilities might reflect the firm's innovation strategy and the learning behavior chosen to support that strategy. The coefficients from the previous analysis might be biased if endogeneity of ambidextrous learning is driving the results. A standard approach to eliminating endogeneity bias is instrumental variable (IV) estimation. Unfortunately, our context does not provide an IV that fulfills the strength and validity requirements. We use R&D intensity to proxy for innovation strategy to investigate the potential endogeneity problem, based on the argument that the firm's innovation strategy will dictate the level of engagement in R&D. We control for R&D intensity in all regression models. Also, when we split the sample based on the median of R&D intensity and perform the same regression on both high and low R&D intensity firms separately, our results hold for both groups.

Second, given the cross-sectional nature of our data, we have some concern that our results might be driven by other types of heterogeneity across firms. For example, high performance firms may be better able to bear the costs of ambidexterity and to pursue certain types of

innovation, and large sized firms may be more suited to ambidexterity and innovation. We conducted a series of split group analyses to rule out these possibilities. First, using a self-reported performance measure, we conducted a group analysis for the two groups of sample firms—high performing and low performing. Overall, the results hold for both groups separately, suggesting that they are not driven by differences in firm performance. We conducted a similar split group analysis for large and small firms. Again, by and large, the results are consistent across the two groups.

Third, we test the sensitivity of the results to other econometric specifications. Other studies employ OLS regression. We therefore reran the analyses with OLS regression. The results of the OLS regressions are similar to the results of the SUR regressions. So even though the SUR regressions may have some major econometric advantages over the simple OLS regressions, we can conclude that our results are not driven by our specific choice of econometric estimator.

Although we did not theorize on this issue, it is possible that the effects of the two dimensions of ambidexterity jointly will be mutually beneficial and will have positive interaction effects on the firm's innovation capabilities. In relation to incremental innovation capability, we have argued in favor of a positive effect of combined ambidexterity. However, despite contending that the balance dimension of ambidexterity *per se* is not important in relation to incremental innovation capability, it could be argued that the positive effect of combined ambidexterity on the firm's incremental innovation capability should be stronger if ambidexterity is also well balanced. In this context, provided that there is a high level of synergy between exploration and exploitation, a high degree of balance could also be helpful for incremental innovation since even incremental innovation might face some level of resistance if

organizational inertia is very strong. In other words, absence of resistance could enhance the effect of combined ambidexterity on incremental innovation capability.

In relation to radical innovation capability, it could be argued that the positive effect of the balance dimension of ambidexterity on radical innovation should be stronger with high than with low levels of combined ambidexterity. When the balance of ambidexterity is high, i.e., when the firm's exploratory and exploitative learning are evenly matched, the firm displays strong signs of overcoming organizational inertia. However, in the presence of balanced ambidexterity, it may also be beneficial for radical innovation capability for the firm also to possess high levels of resources and knowledge, reflected in a high level of combined ambidexterity.

To test these possibilities, we perform a three-way interaction (exploration × exploitation × combined) after accounting for all two-way interactions, following a hierarchical moderated regression procedure (Jaccard, Wan, & Turrisi, 1990). As shown in Appendix A, the regression results provide strong evidence of positive interaction between combined and balance of ambidexterity for both incremental and radical innovation capabilities.

CONCLUSION AND DISCUSSION

Ambidexterity is becoming established as an emerging research paradigm in organizational theory (Raisch & Birkinshaw, 2008) and is a topic of debate over significant and complex organizational phenomena (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; Jansen, Tempelaar, Van Den Bosch, & Volberda, 2009; Lubatkin, 2006). We have noted that the importance of ambidexterity for practice is part of the many prescriptions for improved firm performance and survival (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996). However, although innovative outcomes are at the heart of ambidexterity hypotheses, the literature on ambidexterity pays little

attention to the ambidexterity–innovation link. In differentiating between the two dimensions of ambidexterity—combined and balance—our study yields novel insights.

Specifically, we have established theoretically and corroborated empirically that combined ambidexterity drives incremental innovation capability, and that the balance of ambidexterity influences radical innovation capability. As combined ambidexterity increases, the firm is likely to be exposed to more and better technological opportunities to produce new and refined products. Balance of ambidexterity is required to challenge existing assumptions about the development of radical innovation. These findings question the wisdom of "more is better" for organizational learning (Cohen & Levinthal, 1990; Zahra, Ireland, & Hitt, 2000). High levels of ambidextrous learning may benefit the development of incremental innovation by adding or patching together discrete pieces of knowledge but in the case of radical innovation "more" learning does not help. What matters is balanced learning to overcome organizational inertia. These results have important theoretical implications. The organizational learning literature focuses mainly on types of learning (i.e., exploitation and exploration) for predicting types of innovative outcomes, without explicitly considering how balance of learning might play a role in affecting innovative outcomes. We have established theoretically and empirically that the balance of learning is a central aspect in this context.

This study has important implications for the ambidexterity literature and for innovation research. First, the debate on organizational ambidexterity is disconnected and complex, and would benefit from specification of the dominant relationships between the most relevant variables (Raisch & Birkinshaw, 2008). By addressing the link between ambidextrous learning and innovation, this study links organizational learning and technological innovation, the main literature streams related to organizational ambidexterity. Although some scholars have theorized

about this linkage (Tushman & O'Reilly, 1996), this relationship is poorly understood from a theoretical point of view and there is little empirical evidence on it. This study contributes to the ambidexterity literature by specifying the critical relationship between ambidexterity and innovation. Second, this study raises question about how exploitation and exploration should be operationalized. There is ambiguity and inconsistency in the interpretation and operationalization of exploration and exploitation in the ambidexterity literature (Li, Vanhaverbeke, & Schoenmakers, 2008). In line with March (1991), some studies investigate exploration and exploitation in terms of learning activity (e.g., He & Wong, 2004). However, there is a stream of research that refers to exploration and exploitation as synonymous with "radical innovation" and "incremental innovation" (e.g., Benner & Tushman, 2003; Greve, 2007; Jansen et al., 2009; Jansen et al., 2006). Our results suggest that the differences between the two approaches are significant and important, and thus it is problematic to equate exploration and exploitation with radical and incremental innovation.

Finally, our study has important implications for the innovation literature. Although theory predicts that the antecedents to incremental and radical innovation differ, the existing empirical work does not support this view. For example, Damanpour (1991) in a comprehensive meta-analytic review, concludes that the predictors of radical and incremental innovation are the same. Similarly, Cardinal (2001) suggests that the difference between radical and incremental innovation may be one of magnitude rather than direction. In line with the theory, we propose two different mechanisms for these two types of innovation, i.e., technological search along a trajectory for firms' incremental innovation capability, and overcoming organizational inertia for their radical innovation capability. The empirical results of this study are consistent with our

propositions, thus our study has the potential to contribute to a new framework for understanding incremental and radical innovation.

LIMITATIONS AND FUTURE WORK

This study has several limitations that open up avenues for future research. First, in trying to link ambidexterity with innovation, we have focused on knowledge acquisition by high tech firms in China. However, innovation capability may be shaped by knowledge acquisition and also the existing knowledge base (Zhou & Li, 2012). Our data do not allow us to assess the existing knowledge base. Future work could try to give a more complete account of the ambidexterity-innovation relationship. Second, the cross-sectional nature of our data does not allow us to test for causality. Future research should adopt a longitudinal approach to the examination of causal relationships. Third, although we use technological opportunity discovery and organizational inertia to frame our hypotheses, we do not measure them directly. Future research on innovation could seek to measure these mechanisms explicitly. Fourth, the positive interaction effect between combined and balance of ambidexterity could be further explored. Finally, our measures of capabilities, exploitation, and exploration rely on managers' judgments. Although our research design was chosen with care, we cannot completely rule out the effects of subjectivity. Objective measures could be applied to validate our propositions. Despite these limitations, we believe that this study reveals the critical relationship between ambidexterity and innovation capabilities and provides a starting point for fruitful future research on ambidexterity.

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TABLE 1
Confirmatory Factor Analysis of Measures

Construct and Source	Operational Measures of Construct	SFL[a]
Fit of Model 1: $\chi 2/df = 2.11$; Root mean squared error of approximation (RMSEA)=0.063; Comparative fit index (CFI)=0.948; Tucker-Lewis index (TLI)=0.938		
Incremental innovation capability (Subramaniam and Youndt 2005) α=.87, AVE= .52, CR=.84	Compared with your major competitors, how would you rate your firm's capability to generate the following types of innovations in the last 3 years?	
	Incremental innovation	
	1. Innovations that reinforce your prevailing product/service lines	.82
	2. Innovations that reinforce your existing expertise in prevailing products/services	.83
	3. Innovations that reinforce how you currently compete	.70
	4. Innovations that build on your existing knowledge and expertise	.67
Radical innovation capability (Subramaniam and Youndt 2005) α=.87, AVE= .71, CR=.88	Radical innovation	.85
	1. Innovations that make your prevailing product/service lines obsolete	
	2. Innovations that fundamentally change your prevailing products/services	.89
	3. Innovations that make your existing expertise in prevailing products/services obsolete	.79
Product development competence exploitation (Atuahene-Gima 2005) α=.87, AVE= .58, CR= .87	Over the last 3 years, to what extent has your firm:	
	1. Upgraded current knowledge and skills for familiar products and technologies?	.70
	2. Invested in enhancing skills in exploiting mature technologies that improve productivity of current innovation operations?	.78
	3. Enhanced competencies in searching for solutions to customer problems that are near to existing solutions rather than completely new solutions?	.72
	4. Upgraded skills in product development processes in which the firm already possesses significant experience?	.82
	5. Strengthened our knowledge and skills for projects that improve efficiency of existing innovation activities?	.79
Product development competence exploration (Atuahene-Gima 2005) α=.87, AVE= .58, CR= .87	1. Acquired manufacturing technologies and skills entirely new to the firm?	.78
	2. Learned product development skills and processes (such as product design, prototyping new products, timing of new product introductions, and customizing products for local markets) entirely new to the industry?	.85
	3. Acquired entirely new managerial and organizational skills that are important for innovation (such as forecasting technological and customer trends; identifying emerging markets and technologies; coordinating and integrating R&D; marketing, manufacturing, and other functions; managing the product development process)?	.73
	4. Learned new skills in areas such as funding new technology, staffing R&D function, training and development of R&D, and engineering personnel for the first time?	.78
	5. Strengthened innovation skills in areas where it had no prior experience?	.65
Fit of Model 2: $\chi 2/df = 1.79$; Root mean squared error of approximation (RMSEA)=0.054; Comparative fit index (CFI)=0.937; Tucker-Lewis index (TLI)=0.924		
Intelligence failure reward system (Joshi and Sharma 2004) α=.73, AVE= .51, CR= .76	In this firm,	
	1. People are rewarded from investigating and learning from failed products and ideas.	.71
	2. People are frequented recognized from documenting the learning from failed projects	.77
	3. People are not punished for failure if they performed efficiently and effective and failed regardless.	.66
Organizational slack (De	1.This firm has uncommitted resources that can quickly be used to fund new strategic initiatives	.73

Luca and Atuahene-Gima 2007) α=.83, AVE= .64, CR= .84	2. We are able to obtain resources at short notice to support new strategic initiatives 3. We have substantial resources at the discretion of management for funding new strategic initiatives.	.78 .88
Inter-functional coordination (Zahra and Nielson, 2002) α=.87, AVE=.65, CR=.88	In this firm 1. The activities of functional units are tightly coordinated to ensure better use our market knowledge. 2. People from marketing, R&D, and other functions play important roles in major strategic market decisions. 3. R&D and marketing and other functions regularly share market information about customers, technologies, and competitors. 4. There is a high level of cooperation and coordination among functional units in setting the goals and priorities for the organization to ensure effective response to market conditions.	.77 .79 .85 .81
Technology uncertainty (Jaworski and Kohli 1993) α=.83, AVE=.56; CR=.84	Please indicate the extent to which each of the statements describes your firm's environment in the past 3 years. 1. It was very difficult to forecast technology developments in our industry 2. Technology environment was highly uncertain 3. Technological developments were highly unpredictable 4. Technologically, our industry was a very complex environment.	.70 .69 .88 .73
Competitor uncertainty (Atuahene-Gima and Li 2002) α=.76, AVE=.54; CR=.77	1. Market competitive conditions are highly unpredictable 2. Competition is quite intense in this industry 3. Competitor activities tended to change quite rapidly	.61 .79 .79
Customer uncertainty [b] (Atuahene-Gima and Li, 2002) α=.74, AVE=.52; CR=.76	1. Customer product demands and preferences were highly uncertain. 2. It was difficult to predict changes in customer needs and preferences. 3. Changes in customers' needs were quite unpredictable.	.63 .70 .83

Note: All items were measured on a seven-point scale

TABLE2
Descriptive statistics and correlations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Radical Innovation Capability															
2 Incremental Innovation Capability	0.05														
3 Combined Ambidexterity	0.02	0.10													
4 Balance of Ambidexterity	0.14	-0.07	0.19												
5 Exploration	-0.13	0.37	-0.21	0.30											
6 Exploitation	-0.11	0.33	-0.22	0.003	0.62										
7 Failure Reward	0.36	-0.08	-0.17	0.22	0.25	0.21									
8 Organizational Slack	0.25	0.23	-0.11	0.18	0.44	0.46	0.41								
9 Inter-functional Coordination	-0.23	0.33	0.06	0.088	0.52	0.51	0.13	0.30							
10 Firm Size	0.08	0.08	0.09	-0.05	0.03	0.08	0.02	0.11	0.01						
11 R&D Intensity	0.05	-0.07	0.03	-0.08	-0.02	0.03	0.003	0.07	0.01	0.007					
12 Willingness to Cannibalize	-0.00	-0.04	-0.25	0.11	0.27	0.33	0.31	0.14	0.27	-0.05	-0.06				
13 Competitor Uncertainty	-0.16	0.24	0.07	0.03	0.31	0.36	0.02	0.23	0.43	-0.03	0.11	0.04			
14 Technology Uncertainty	-0.02	-0.02	-0.07	-0.06	0.03	0.04	0.10	-0.06	0.22	-0.15	0.09	0.34	0.34		
15 Customer Uncertainty	0.05	0.04	0.03	0.13	0.19	0.18	0.31	0.16	0.25	-0.004	0.06	0.33	0.46	0.40	
Mean	3.74	4.91	0.48	6.42	4.69	4.87	3.28	4.32	5.04	5.89	11.47	4.54	5.19	4.69	4.69
S.D.	1.29	0.88	1.25	0.54	0.89	0.88	0.83	1.18	0.98	1,00	11.49	1.02	0.87	1.01	0.92

Note. Correlation coefficients above |0.13| are statistically significant at the 5% level.

TABLE 3
Results of Regression Analysis for Incremental Innovation Capability

	(1)	(2)	(3)	(4)
Failure Reward	-0.23 **	-0.21 **	-0.21 **	-0.18 *
	(0.08)	(0.08)	(0.08)	(0.08)
Organizational Slack	0.09	0.09	0.10 †	0.10 †
	(0.06)	(0.06)	(0.06)	(0.06)
Inter-functional Coordination	0.14 *	0.11	0.14 *	0.09
	(0.07)	(0.07)	(0.07)	(0.07)
Firm Size	0.06	0.04	0.05	0.02
	(0.06)	(0.06)	(0.06)	(0.06)
R&D Intensity	-0.01 †	-0.01 †	-0.01 †	-0.01 *
	(0.00)	(0.00)	(0.00)	(0.00)
Willingness To Cannibalize	-0.15 *	-0.13 †	-0.14*	-0.10
	(0.06)	(0.07)	(0.06)	(0.06)
Competitor Uncertainty	0.03	0.03	0.04	0.03
	(0.08)	(0.08)	(0.08)	(0.08)
Technology Uncertainty	0.02	0.03	0.00	0.01
	(0.06)	(0.06)	(0.06)	(0.06)
Customer Uncertainty	-0.00	-0.02	0.01	-0.01
	(0.08)	(0.08)	(0.08)	(0.07)
Ownership Type	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Exploration	0.22 **	0.25 **	0.28 **	0.34 **
	(0.08)	(0.08)	(0.09)	(0.09)
Exploitation	0.14	0.16 †	0.09	0.10
	(0.09)	(0.09)	(0.09)	(0.09)
Combined Ambidexterity		0.08 †		0.13 **
		(0.05)		(0.05)
Balance of Ambidexterity			-0.23 *	-0.33 **
			(0.11)	(0.11)
Constant	3.20 **	3.09 **	4.58 **	5.00 **
	(0.59)	(0.58)	(0.87)	(0.87)
N	204	204	204	204
R2	0.27	0.28	0.29	0.31

Note: Standard errors in parentheses
† $p < .10$
* $p < .05$
** $p < .01$
Two-tailed tests

TABLE 4

Results of Regression Analysis for Radical Innovation Capability

	(5)	(6)	(7)	(8)
Failure Reward	0.48 **	0.49 **	0.45 **	0.45 **
	(0.11)	(0.11)	(0.11)	(0.11)
Organizational Slack	0.34 **	0.34 **	0.33 **	0.33 **
	(0.08)	(0.08)	(0.08)	(0.08)
Inter-functional Coordination	-0.28 **	-0.30 **	-0.28 **	-0.28 **
	(0.10)	(0.10)	(0.10)	(0.10)
Firm Size	0.09	0.08	0.11	0.11
	(0.08)	(0.08)	(0.08)	(0.08)
R&D Intensity	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)
Willingness To Cannibalize	-0.08	-0.06	-0.09	-0.09
	(0.09)	(0.09)	(0.09)	(0.09)
Competitor Uncertainty	-0.20 †	-0.20 †	-0.21 †	-0.21 †
	(0.12)	(0.12)	(0.12)	(0.12)
Technology Uncertainty	0.09	0.10	0.11	0.11
	(0.09)	(0.09)	(0.09)	(0.09)
Customer Uncertainty	0.07	0.06	0.05	0.05
	(0.11)	(0.11)	(0.11)	(0.11)
Ownership Type	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Exploration	-0.21 †	-0.19	-0.29 *	-0.28 *
	(0.12)	(0.12)	(0.12)	(0.13)
Exploitation	-0.10	-0.08	-0.02	-0.02
	(0.13)	(0.13)	(0.13)	(0.13)
Combined Ambidexterity		0.07		0.02
		(0.07)		(0.07)
Balance of Ambidexterity			0.35 *	0.34 *
			(0.16)	(0.17)
Constant	3.67 **	3.58 **	1.60	1.66
	(0.83)	(0.84)	(1.24)	(1.26)
N	204	204	204	204
R^2	0.31	0.31	0.32	0.32

Note: Standard errors in parentheses
† $p < .10$
* $p < .05$
** $p < .01$
Two-tailed tests

APPENDIX A

Table A1
Regression Results of Interaction Effects

	Incremental Innovation Capability		Radical Innovation Capability	
	(9)	(10)	(11)	(12)
Failure Reward	-0.21 **	-0.18 *	0.43 **	0.49 **
	(0.08)	(0.07)	(0.11)	(0.10)
Organizational Slack	0.12 *	0.14 **	0.34 **	0.40 **
	(0.06)	(0.05)	(0.08)	(0.07)
Inter-functional Coordination	0.08	0.06	-0.28 **	-0.32 **
	(0.07)	(0.07)	(0.10)	(0.09)
Firm Size	0.02	-0.02	0.12	0.03
	(0.06)	(0.05)	(0.08)	(0.08)
R&D Intensity	-0.01 *	-0.01 *	0.00	0.00
	(0.00)	(0.00)	(0.01)	(0.01)
Willingness To Cannibalize	-0.09	-0.11 †	-0.08	-0.13
	(0.06)	(0.06)	(0.09)	(0.09)
Competitor Uncertainty	0.02	0.06	-0.22 †	-0.13
	(0.08)	(0.08)	(0.12)	(0.11)
Technology Uncertainty	0.01	0.03	0.10	0.16 †
	(0.06)	(0.06)	(0.09)	(0.08)
Customer Uncertainty	-0.01	-0.02	0.05	0.03
	(0.07)	(0.07)	(0.11)	(0.10)
Ownership Type	Yes	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes	Yes
Exploration	0.19	0.10	-0.29 †	-0.49 **
	(0.12)	(0.11)	(0.17)	(0.16)
Exploitation	0.31 *	0.35 **	0.02	0.12
	(0.13)	(0.12)	(0.18)	(0.17)
Combined Ambidexterity	0.14 **	0.01	0.01	-0.27 **
	(0.05)	(0.06)	(0.07)	(0.08)
Balance of Ambidexterity	-0.39 **	-0.20 †	0.27	0.68 **
	(0.12)	(0.12)	(0.17)	(0.17)
Exploration × Balance	-0.35 **	-0.28 *	-0.24	-0.06
	(0.13)	(0.12)	(0.18)	(0.17)
Exploitation × Balance	0.18	0.26 *	-0.07	0.09
	(0.12)	(0.12)	(0.18)	(0.16)
Combined × Balance		0.35 **		0.75 **
		(0.08)		(0.12)
Constant	5.35 **	4.26 **	2.05	-0.32
	(0.87)	(0.87)	(1.27)	(1.21)
N	204	204	204	204
R2	0.34	0.39	0.34	0.45

Note: Standard errors in parentheses
† $p < .10$
* $p < .05$
** $p < .01$
Two-tailed tests

CHAPTER THREE

Standards Gold Rush?

A Longitudinal Study of Standard Participation and Innovation Performance

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Abstract

This paper examines the association between firms' standard participation and innovation performance. Drawing on the knowledge-based view (KBV) of the firm, I argue that the firm's standard participation is curvilinearly associated with its innovation rate due to incoming knowledge spillovers, and positively associated with its share of exploitative innovation due to the threat of outgoing knowledge spillovers. I would argue also that these associations are contingent on the extent to which the firm is research and development active. Panel data from 270 firms in the information and communication technology industries are used to test the hypotheses. While the inclusion of technologies in an industry standard can provide competitive advantage and substantial royalty revenues, the evidence provided by this paper suggests that standard participation may promote potential liabilities, which managers need to weigh against the benefits of participation, or seek to circumvent.

1. Introduction

> *The noisiest of those competitive battles will be about standards. The eyes of most sane people tend to glaze over at the very mention of technical standards. But in the computer industry, new standards can be the source of enormous wealth, or the death of corporate empires. With so much at stake, standards arouse violent passions.*
>
> (The Economist, February 23, 1993)

The shift towards increasing complexity in modern products has made standards of vital importance in the Information and Communication Technology (ICT) sector. Defined as codified specifications that detail how the components of a technical system interact (Garud, Jain, & Kumaraswamy, 2002; Leiponen, 2008), standards exist to ensure the compatibility of equipment from various manufacturers (e.g., wireless telephone handsets), and interoperability among the components of a complex technology (e.g., handsets and wireless service). Egan (2002) indicates that standards have become "the new guns in global competition", and are driving industry growth and technological developments. Nations such as China, India, and the United States consider standard-setting to be a crucial element in their industrial policy strategies. Firms such as Microsoft, Samsung, Intel, and Qualcom, rely on their ability to contribute their technologies to the dominant standards in their industries to maintain and/or improve their competitive position (Hill, 1997). The wide and intensified interest in influencing standard-setting can be described as "standards gold rush".

Stressing the beneficial effects of standard participation, recent empirical works on this standards gold rush investigate the strategies employed by firms to influence standard-setting (Bekkers, Bongard, & Nuvolari, 2011; Leiponen, 2008), the incentives for firms to join standard setting organizations (SSOs) (Blind, 2006; Waguespack & Fleming, 2008), and the impacts of standardization participation on the intellectual property (IP) strategies of participating firms

(Simcoe, Graham, & Feldman, 2009) and the value of disclosed patents (Rysman & Simcoe, 2008). However, firms' standardization efforts also involve significant investment costs. Participation in SSOs involves expenses such as membership fees, travel, meetings and human resources costs. Hawkins's (1999) estimate of the membership fees incurred by a typical technology firm in the mid-1990s is around US$1.5 million, while IBM's spending on standard development in 2005 was reported as amounting to US$500 million – roughly 8.5% of its research and development (R&D) budget (Rysman & Simcoe, 2008). Furthermore, standardization efforts require adjustments to the internal organizational structures and human resources policies to accommodate the requirements of standards development (Ratanawaraha, 2006). For example, Huawei has group-level organizations that specialize in industry standard R&D, supplemented by units focusing on standards related to each business group. The standards team comprises over 400 experts.[2]

An important feature of current standard-setting is that "standards are set in a more cooperative manner" (Leiponen, 2008: 1904). Specifically, SSOs are used by firms as R&D coordination platforms: by discussing and jointly drafting technical specifications with other firms within the SSO, firms can coordinate their efforts to create technological solutions and technology markets (Leiponen, 2008; Rysman & Simcoe, 2008). Indeed, large numbers of innovative technologies, such as GSM, WCDMA, WiFi and MPEG, have been developed through joint standardization efforts (Pohlmann, 2012). The firm's ability to contribute its technologies to the dominant standards through SSOs, i.e., standard participation, is a critical determinant of its long-term competitive position and business performance (Hill, 1997). Researchers report that standard participation increases firms' revenues (Leiponen, 2008), helps legitimate start-ups (Waguespack & Fleming, 2008) and emerging technologies (Rysman & Simcoe, 2008), and brings competitive advantage (Dokko & Rosenkopf, 2009).

[2] http://www.huawei.com, retrieved on November 23, 2012.

Despite the wealth of literature on the phenomenon of the standards gold rush, it is still "an important but understudied aspect of technology strategy" (Leiponen, 2008: 1904). First, while recent works focus on *how* a firm can influence standard-setting to favor the development of its technologies (Bekkers et al., 2011; Leiponen, 2008), few empirical studies examine *whether* standard participation enhances or hampers participating firms' innovation performance. Layne-Farrar et al. (2011) recommend caution in treating a firm's participation in standard-setting as given, and argue that it involves an important firm decision (see also (Axelrod, Mitchell, Thomas, Bennett, & Bruderer, 1995). Fomin et al. (2003) call for deeper investigation of the technological innovation inherent in ICT standard-setting activities. Participation in standard-setting involves significant investment costs and risks; thus, an important issue for both researchers and practitioners is to determine how standard participation is related to firms' innovation performance.

This paper extends the stream of theoretical and empirical research on the standards gold rush by investigating the relationship between firms' standard participation and their innovation performance. It focuses on two questions. First, how a firms' standard participation is associated with its rate and direction of innovation activities. Second, to what extent these associations might be contingent on the firm's internal R&D. These are important questions that are mostly unresolved. On the one hand, there are some authors who predict that having its technologies included in a standard can enhance the firm's innovation performance by shaping the institutional and technological environment of its technologies (Spencer, 2003; Yang, Phelps, & Steensma, 2010). On the other hand, concern has been expressed that standard participation might result in misappropriation by competitors through outgoing knowledge spillovers. Specifically, standard participation is argued to be curvilinearly associated with firms' innovation rates due to of incoming knowledge spillovers, and to be positively associated with firms' shares of exploitative innovation

due to the threat of outgoing knowledge spillovers. I hypothesize further about contingency effects of R&D intensity on the relationship between standard participation and innovation performance.

A panel of 270 ICT firms for the period 1996–2005 is used to test these hypotheses. Disclosure letters from four major SSOs, data from the National Bureau of Economic Research (NBER) patent database and the COMPUSTAT database were combined to identify standard participation and innovation performance. The number of patent applications and amounts of new external knowledge are used to capture the rate of innovation, and proportion of exploitative patents, i.e., patents that build solely on the firm's existing knowledge, is used to capture the direction of innovation. I report two findings. First, when considering the entire population, the association between the extent of standard participation and rate of innovation can be described as an inverted-U shaped relationship. However, this inverted-U shaped relationship is shown to hold only for high R&D intensity firms; low R&D intensive firms exhibit a linear positive relationship between the extent of standard participation and the innovation rate. Second, the extent of standard participation is positively related to the participating firm's share of exploitative innovation. In other words, standard participation is associated with the participating firm's innovation directed toward exploitation. Robustness checks were conducted to reduce concerns that shifts in the technology life cycle might be driving the results. Thus, while prior research on standardization emphasizes the benefits of standard participation, including competition effects (e.g., Dokko & Rosenkopf, 2009), revenue effects (e.g., Leiponen, 2008), and endorsement effects (e.g., Rysman & Simcoe, 2008; Waguespack & Fleming, 2008), this paper provides quantitative evidence on both the benefits and costs of standard participation, which managers need to evaluate in deciding about standard participation.

The remainder of the paper is organized as follows. Section 2 explores the literature. Section 3 presents the theoretical arguments and hypotheses driving the analysis. Section 4 describes empirical setting and empirical strategy. Section 5 presents the results, and Section 6 discusses additional analysis. The paper concludes with a discussion and implications for further research in Section 7.

2. Theoretical Background

2.1 Standard Participation and Standard Essential Patents

The shift towards increasing complexity in modern products and fragmented ownership of IP rights has made standards vitally important in the ICT sectors. A case in point is the smartphone, which combines a phone with email, camera, video players, music player, online gaming. and GPS tracking systems, among other features. Standards allow all the firms involved, such as handset producers, wireless network providers, and software producers, to coordinate their activities to ensure the proper functioning of smartphones. Standards are codified specifications for how the components of a technical system interact (Garud, Jain, & Kumaraswamy, 2002; Leiponen, 2008). They exist to ensure the compatibility of equipment from various manufacturers (e.g., wireless telephone handsets) and interoperability among the components of a complex technology (e.g., handsets and wireless service), and thus have a significant influence on industry growth and technology developments (Dokko & Rosenkopf, 2009).

In the present study, standard participation is defined as being successful in having the firm's technology included in a standard. Note that standard participation is used in the literature to refer to both participation in standard-setting organizations (Dokko & Rosenkopf, 2009; Waguespack & Fleming, 2008), and contribution of technology to the standard (also referred to as standard contribution) (Rysman & Simcoe, 2008). In the context of this paper, standard participation is in

line with the latter view, which reflects the results of the firm's standard-setting efforts. It is important to note also that the present study adopts a firm-level view of standard participation. Firms' standardization activities differ greatly; to acknowledge this, the present study uses extent of standard participation to capture the degree to which firms vary in their ability to contribute their technologies to a standard.

Standard participation is identified by ownership of essential patents. The European Telecommunications Standards Institute (ETSI) defines a patent as essential when "it is not possible on technical (but not commercial) grounds, taking into account normal technical practice and the state of art generally available at the time of standardization, to make, sell, lease, otherwise dispose of, repair, use, or operate equipment or methods which comply with a standard without infringing that IPR" (ETSI 2008).[3] The process of standard participation depends on technical as well as social factors (Bekkers et al., 2011; Tushman & Rosenkopf, 1992). In order for a firm's technology to be included in a standard, it needs to contribute knowledge that is superior to that of its competitors. Using patent citation data, Rysman and Simcoe (2008) confirm that SSOs successfully attract promising technologies to be included in standards. However, the technology is not the sole factor determining inclusion in a standard. For example, in the case of complex technologies, there are often no technological options that are objectively superior on all dimensions (Dokko & Rosenkopf, 2009). In these cases, social factors, such as co-membership of industry consortia (Leiponen, 2008) and firm's market power (Weiss & Sirbu, 1990), can be significant determinants increasing the chances that the technology will be adopted as a standard.

The impact on a firm of being included in or excluded from an important standard can be substantial. Firstly, it can be particularly lucrative for firms to out-license standards-related IP rights. For example, Qualcomm receives several billion dollars in annual royalties for its patents which are

[3] ETSI Rules of Procedure, November 26, 2008, http://www.etsi.org/

essential to the CDMA cellular telephony standard (Simcoe et al., 2009). In addition to substantial economic benefits, essential patents also open up strategic directions for the firm. Cohen et al. (2009: 58) suggest that "[E]ssential patents define a subset of important R&D, are seen that way from the outset, and involve a wide range of company assets and expertise, not just a specific technical capability." Finally, standards favor one firm's technologies, yielding competitive advantage for that firm because other competing technologies are locked out of the market. Thus, some authors suggest that influence over which standards are developed and adopted is an important aspect of high-technology firms' performance (Dokko & Rosenkopf, 2009).

Given the importance of essential patents, control over standard essential patents has promoted fierce competition among firms. For instance, in 2010, an astonishing bid of US$4.5 billion was made by a consortium that included Apple, Microsoft, Sony, Ericsson and RIM, for 6,000 standard essential patents relating to 3G and 4G technologies, to Nortel Networks.[4] In 2011, Google purchased Motorola Mobility for US$12.5 billion with the main objective of acquiring ownership of Motorola Mobility's patent portfolio which is known to include many standard essential patents.[5] These transactions are evidence of the value that companies attach to standard participation and standard essential patents.

2.2 Standard-setting Organizations as Innovation Coordination Platforms

Voluntary SSOs are important for standard development and promotion. Through voluntary and open membership, these SSOs work to provide a forum where interested parties can seek consensus on shared product design aspects, and a mechanism for collective endorsement of new standards (Simcoe et al., 2009). The literature highlights the increasingly central role of SSOs in

[4] http://dealbook.nytimes.com/2011/07/01/apple-and-microsoft-beat-google-for-nortel-patents/
[5] http://www.bloomberg.com/news/2011-08-15/google-agrees-to-acquisition-of-motorola-mobility-for-about-12-5-billion.html

coordinating technology developments in the ICT industries (Bar & Leiponen, forthcoming; Blind, 2006; Delcamp & Leiponen, 2012; Pohlmann, 2012; Rysman & Simcoe, 2008). SSOs constitute an important innovation coordination platform for firms because the issue and adoption of a new standard involves the common adoption of thousands of complementary technological inventions, including competitors', users', suppliers' and those of other stakeholders (Blind, 2006; Pohlmann, 2012). Indeed, a large number of modern innovative technologies, such as GSM, UMTS, WCDMA, WiFi, MPEG, Blue-Ray, etc., were developed jointly by SSOs' participating firms during the standards process (Pohlmann, 2012). Furthermore, standards convey technological information about products and processes, which represents innovation opportunities for SSO participating firms. Taking the perspectives of firms in developing countries, Ratanawaraha (2006) documents how Asian firms such as Samsung and LG, maintain their technological innovation through participating in and leading standardization in SSOs. In sum, to paraphrase Huawei, standard-setting participation is vital for solution interoperability, R&D efforts, and multilateral cooperation efforts, among others.[6]

The strategic use of SSOs for the development of innovation can be understood from the perspective of the KBV of the firm, in which a firm's superior access to and recombination (or integration) of knowledge are key to its ability to innovate and ultimately to compete (Grant, 1996a, b; Kogut & Zander, 1992). At its core, innovation is a path-dependent, cumulative activity that involves multiple firms (Grant, 1996a). Each firm privately invests in R&D to expand its knowledge base in order to be able to create innovative products; meanwhile, knowledge can "spill over" to other firms, to the disadvantage of the focal firm (Lavie, 2006; Myles Shaver & Flyer, 2000). In this spirit, innovation scholars suggest that novel innovations arise not just from combining ideas from the firm's core areas of expertise but even more through their recombination

[6] http://www.huawei.com, retrieved on November 23, 2012.

with ideas from outside (March, 1991). Thus, an effective innovation strategy is driven by maximizing the benefits of incoming spillovers and minimizing the costs of outgoing spillovers (Cassiman and Veugelers 2002). In order to maximize the benefits of incoming spillovers, the firm establishes external collaborations to tap into the knowledge bases of its partners (Powell et al. 1996), builds absorptive capacity to effectively scan, screen, and absorb external produced spillovers (Cohen and Levinthal 1990), or invests in learning-by-hiring to access critical knowledge (Song et al. 2003). At the same time, the firm minimizes the costs of outgoing spillovers, and raises knowledge barriers by investing in causal ambiguity (Reed and Defillippi 1990), contractual/equity control (Das and Teng 1999), and use of appropriability mechanisms such as patents and lead times (Cassiman & Veugelers, 2002; Levin, Klevorick, Nelson, & Winter, 1987).

Applying the theoretical framework of the KBV to standard participation, the two forces of maximizing the benefits of incoming spillovers and minimizing the costs of outgoing spillovers can significantly affect innovation in participating firms in the ICT industries. Standard participation not only keeps firms up to date with the latest technical developments in the industry but also attracts more innovators towards the focal firm's technological trajectory, leading to the development of a pool of incoming knowledge spillovers (Spencer, 2003; Yang et al., 2010). The dilemma is that while standard participation might benefit the firm's innovation performance, it introduces concerns related to outgoing knowledge spillovers. Delcamp and Leiponen (2012) suggest that the risks of outgoing spillovers as the result of participation in standard-setting are particularly high because all participants have sufficient skills to understand and absorb these competencies. For example, Apple stated publicly that it was "deeply concerned by the rampant abuse of standards-essential patents by some of our competitors"[7]. In order to have a more comprehensive understanding of the relationship

[7] Source: http://www.nytimes.com/2012/10/08/technology/patent-wars-among-tech-giants-can-stifle-competition.html?pagewanted=all

between standard participation and the firm's innovation performance, this paper investigates both the rate and direction of firm innovation following standard participation.

3. Hypotheses

3.1 Standard Participation and the Rate of Innovation

Standard participation represents a specific form of knowledge sharing. Ratanawaraha (2006) suggests that the standardization process is a process of converting tacit, localized, and proprietary knowledge into generic, explicit knowledge for utilization by other firms. In contrast to the conventional view that openly sharing the firm's knowledge will erode its competitive advantage, some recent studies identify several benefits associated with sharing valuable firm knowledge, including the development of a knowledge spillovers pool (Yang et al., 2010), reshaping the collaborative behavior of others (Alexy, George, & Salter, 2013), and gaining access to recipients' knowledge (Appleyard, 1996). This stream of work recognizes that firms are part of larger innovation ecosystems and are dependent on the behavior of others to achieve superior innovation performance, and suggests that firms can enhance their innovation performance by proactively managing incoming spillovers (e.g., Alexy et al., 2013; Spencer, 2003; Yang et al., 2010).

Standard participation may be positively related to the firm's rate of innovation for two reasons. First, standards determine the technologies and expertise that are required to deliver offers. Having the firm's technology included in a standard yields competitive advantage for the participating firm because it allows it to rely on its existing technological capabilities rather than having to acquire new ones. For example, when Sony won the DVD format war against Toshiba in 2008, it was able to keep up with innovation in Blu-ray technologies, while it took Toshiba over a year to launch its first Blu-ray product because it had to switch from HD DVD to the Blu-ray technology.

Second, having the firm's technology included in a standard influences all innovators' technical priorities and attracts more innovators to the firm's technological trajectory. Thus, standard participation leads to the development of a sizable incoming knowledge spillovers pool (Yang et al., 2010). This pool of incoming knowledge spillovers allows the focal firm to observe how recipient firms link external knowledge components to its technology which in turn, facilitates identification of potentially promising knowledge and combinations for future innovation. For example, Yang et al. (2010) describe how Kodak's successive innovation performance in OLED was enhanced by attracting and tracking the innovative efforts of recipient rivals. In addition to rival firms, suppliers and complementors also provide inputs to the focal firm's incoming spillovers pool. Standards can spark a bandwagon effect: once the technology is legitimized by a standard, more firms will invest in complementary products for the technology, making it more attractive for more firms to jump onto the bandwagon (Soh, 2010). An increase in the number of suppliers and complementors working on the disclosed technology can effectively generate feedback for future innovation.

However, there may be diminishing benefits to standard participation for innovation development. Although standard participation facilitates the development of an incoming spillovers pool, as the extent of standard participation increases, the overlap between the firm's prior knowledge and new knowledge acquired from standards participation may increase. First, adding overlapping knowledge will not provide additional input to the firm's innovation creation. Second, exposure to overlapping knowledge can hamper the firm's ability and motivation to acquire other valuable new information, thus negatively affecting the firm's innovation ability (Rindfleisch & Moorman, 2003; Rowley, Behrens, & Krackhardt, 2000).

Constant costs (from outgoing spillovers and necessary managerial and engineering resources) for standard participation in every project combined with decreasing marginal benefits from

standard participation, the relationship between extent of standard-setting participation and the firm's rate of innovation will take an inverted u-shape. In sum, the optimal level of standard-setting participation is achieved when the participating firm finds the right balance between valuable incoming knowledge spillovers and damaging knowledge redundancy. Accordingly, I propose that:

H1: The firm's extent of standard-setting participation is curvilinearly (takes an inverted U-shape) related to the rate of innovation.

3.2 Standard Participation and the Direction of Innovation

Outgoing knowledge spillovers represent part of the cost-side of standard-setting participation, and firms may act strategically in their innovation activity to reduce the level of outgoing knowledge spillovers. For its technology to be included in a standard, the firm needs to convert tacit, localized, and proprietary knowledge into generic, explicit knowledge able to be utilized by other firms (Ratanawaraha 2006). The outgoing spillovers concern is exacerbated when the firm is revealing its most promising technologies in order to become part of the standard (Rysman and Simcoe 2008). Therefore, standard participation conveys important information for the competition and disseminates some of the firm's important knowledge broadly and rapidly. This increases the incentives for participating firms to protect themselves from the detrimental effects of outgoing spillovers. For example, Simcoe et al. (2009) finds that litigation rates for SSO patents are 5.5 times higher than the rate among a random sample of patents from the same technology class.

Standard participation increases concern over outgoing spillovers to the extent that the firm's technologies become more valuable and more visible. Standard participation provides the focal firm's technologies with legitimacy (Rysman & Simcoe, 2008; Waguespack & Fleming, 2008) and reduces the uncertainties associated with them. Standards frequently are developed at an early stage in a technology's evolution when there is a variety of promising alternative technologies with

uncertain relative virtues (Chiao, Lerner, & Tirole, 2007). In providing a "stamp of approval," SSOs serve as a form of third-party endorsement that increases the visibility and perceived quality of the chosen technology. For example, Rysman and Simcoe (2008) empirically show that standard participation substantially increases patent citations to the standardized technology. The increased legitimacy and visibility and reduced uncertainties provided by inclusion in a standard increases the urgency for the firm to protect itself against the knowledge leakage through outgoing spillovers.

Most contributions consider litigation as a means of minimizing outgoing spillovers (e.g., Simcoe et al. 2009). However, the present paper investigates a different protection mechanism in the form of an increased emphasis on exploitative innovation. An exploitative innovation is defined as an innovation that depends solely on the firm's existing knowledge. Exploitative innovation may or may not represent improvements to a disclosed technology but it may deter misappropriation by the competition by making close substitutes costly. Compared to the protection endowed by litigation which is only observed if the patentee decides actively to enforce its legal rights and the bargaining process fails (Simcoe et al. 2009), measurement of exploitative innovation captures the firm's protection motives from the outset of the standard participation process, regardless of its negotiation power and legal rights. To summarize, I propose that:

H2: A firm's extent of standard participation is positively related to its subsequent share of exploitative innovation output.

3.3 Standard Participation and Internal R&D Investment

Investment in R&D enables the creation and absorption of new knowledge by the firm, and thus, is regarded as a major driver of innovation (Cohen & Levinthal, 1989). I argue that R&D investments moderate the inverted U-shaped relationship between standard participation and the innovation rate, such that the downward-bending part of the relationship is more pronounced for

firms that invest heavily in R&D compared to firms that make relatively low levels of investment in R&D. This reasoning builds on the logic underlying Hypothesis 1. Firms involved in high levels of R&D activity create large amounts of in-house knowledge which increases the chances that the firm will experience decreasing benefits for innovation from incoming knowledge spillovers due to substantial overlaps between the in-house knowledge and the incoming knowledge. Conversely, for firms with less in-house knowledge (lower levels of R&D) the chance of such knowledge overlaps as a result of standard participation is relatively small. In sum, I would hypothesize that:

H3: High R&D-intensive firms are more likely than low R&D intensive firms to show a concave relationship between standard participation and the innovation rate.

As already argued, standard participation is positively related to the share of exploitative innovation because of the threat of outgoing spillovers. I would expect a high R&D intensive firm to be more concerned about knowledge leakage via outgoing spillovers than a firm with low level investment in R&D. Arrow (1962) suggests that firms have strong incentives to protect their R&D investments from spilling over to other firms and invest in knowledge protection mechanisms such as ambiguity to prevent unwanted outgoing spillovers. Veugelers and Cassiman (1999) show that firms with effective protection mechanisms, such as secrecy, lead time, or complexity, are more likely to engage in intensive internal R&D activities. In other words, a firm with high levels of R&D investment will be more sensitive to the threat of outgoing knowledge spillovers than a low R&D intensity firm, which argues for a positive moderating effect of R&D intensity on the relationship between standard participation and share of exploitative innovation. Furthermore, the not-invented-here (NIH) syndrome suggests that the perceived value of internal knowledge increases as internal R&D intensity increases. Thus, compared with a firm with low levels of R&D activity, a highly R&D intensive firm will attach higher importance to its internal knowledge and

have a stronger incentive to protect its internal knowledge from the spilling over. Combining these arguments, formally I propose that:

H4: The positive relationship between standard participation and share of exploitative innovation output is stronger for firms with high levels of R&D investment than for firms with low levels of R&D investment.

4. Data and Measurement

The research setting for this study is the ICT industries. Firms in these industries "produce and market hardware and software that enable the transmission, switching, and reception of voice, images, and data over both short and long distances using digital, analog, wire line, and wireless technology" (Phelps, 2010: 896). The ICT industries offer many advantages for the current study. First, given that ICT technologies are networked, ubiquitous, and complex, ICT industries rely heavily on SSOs and standards. Indeed, the ICT sector is one of the most standard-intensive sectors. Second, ICT firms actively and systematically patent their inventions, allowing use of patent data for multiple measures (Phelps, 2010; Yang et al., 2010).

This study relies on a combination of data sources: SSO disclosure data from Rysman and Simcoe (2008), the NBER patent database (Hall, Jaffe, & Trajtenberg, 2001) and the COMPUSTAT database. Several practical considerations guided the construction of the sample. A policy of disclosure was widely adopted by various SSOs after 1994, so I limited the period of study to 1996–2005 (Bekkers & West, 2009). I adopted one-year lead measurements for innovation performance so the study ends in 2005 because the NBER patent database covers the period to 2006. Collection of data on every ICT firm independent of its standard-setting behavior began by identifying all ICT firms that met the following two criteria during the study period: 1) having patenting records at the U.S. Patent and Trademark Office (USPTO); 2) having reliable financial

data available from the COMPUSTAT database. Due to these restrictions, the sample is biased towards large publicly owned firms which must be considered when interpreting the results.

Next, I constructed a data set of SSO disclosure data, based on Rysman and Simcoe (2008). A disclosure typically is a letter or e-mail message indicating that a firm owns (or may own) IP that is relevant to a proposed standard. Disclosure letters usually include licensing terms, while a specific patent number might or might not be included. Firms might also indicate their unwillingness to participate in a proposed standard by including a non-license term for their IP. The present study includes four SSOs – the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), the Internet Engineering Task Force (IETF) and the International Telecommunication Union (ITU). The disclosures in the sample are associated with a wide range of technologies, such as DSL (for data transmission over phone lines) and TDMA (a cellular telephony protocol) at ANSI, WiFi at IEEE, TCP/IP (internet transport protocols) and DHCP (network address allocation) at IETF. There are a few advantages to including these four SSOs: (1) they are the ones with the largest global impact and relevance in the ICT standards field (see Rysman and Simcoe (2008) for a detailed description of these four SSOs), (2) the disclosed patents at these four SSOs are closely linked to USPTO patents,[8] (3) reliable disclosure data were available for the study period, and (4) the SSOs implement similar disclosure policies (see Bekkers and Updegrove, (2012). Finally, the data sources provide the advantage that the results of this study will be more comparable to those in the prior literature.

I traced each firm's history to account for name changes, division names, mergers, acquisitions, joint ventures, etc., and aggregated the patent data and the disclosure data at firm level. Firm-level financial data were taken from the COMPUSTAT database. The procedures resulted in an unbalanced panel data set of 1,210 observations for 270 public ICT firms.

[8] For this reason, the European Telecommunications Standards Institute (ETSI) is not included.

4.1 Measurement: Dependent Variables

Firm innovation rate is captured by two variables. The first, *patent rate,* is measured as the number of patent applications in a given year t. Patent count has been shown to correlate well with new product introduction and invention count, and has been used as a proxy for innovation outcome (e.g., Ahuja & Katila, 2001; Joshi & Nerkar, 2011; Schilling & Phelps, 2007). However, in the context of standards-setting a patent reflects a successful outcome of innovation and also captures a property right which encourages standard-setting participation. Strategic patenting in the context of the standardization process is a significant issue that has been discussed extensively[9] (Bekkers & West, 2009; Berger, Blind, & Thumm, 2012; Blind, 2006; Layne-farrar, 2008). Thus, the potential endogeneity of patent filing creates a major problem related to empirical identification and requires a means to differentiate between strategic patenting in standard-setting participation, and patenting as a result of new knowledge creation.

The second variable is *the amount of new external knowledge*, measured as the number of new external citations in the firm's patent applications in a given year t. It captures the amount of incoming new knowledge spillovers assimilated and applied in the firm's innovation in a given year t. Use of this measure builds on the knowledge-based argument which suggests that a firm's superior access to and integration of new knowledge are key to its ability to innovate. Therefore, I would expect a strong correlation between the amount of new external knowledge and the firm's rate of innovation. Another advantage of this measure is that it provides a direct test of the knowledge spillovers mechanism. Specifically, if standard participation facilitates incoming knowledge spillovers, we should observe participating firms citing more new external knowledge.[10] Note that patent citations might also be strategic – typically firms tend to withhold external citations

[9] The empirical evidence regarding the perceived issue of strategic patenting in standard-setting, so far is inconclusive.
[10] The source of this external knowledge may not necessarily be other standard participating firms (i.e., other firms with technologies embedded in a standard), it can also come from providers of competing technology.

to obtain the widest claim. Thus, the amount of new external knowledge represents a conservative measure of incoming knowledge spillovers, and any bias created by strategic citation is likely to be negative (i.e., biasing the coefficient towards zero).

The *share of exploitative innovation* is constructed in several steps. First, the extent to which a patent builds on knowledge the firm used in previous patents was assessed by examining the citations. Prior patents cited by a patent were coded as existing firm knowledge (exploitation) if they were either repeat citations (patents the firm had previously cited) or self-citations (the firm's own previous patents) in the past seven years. Phelps (2010) suggests that a seven-year time window is appropriate to account for loss of organizational memory in the ICT industries, since the median age of cited patents is around 6.5 years. Following Benner and Tushman (2002), for each patent I then computed an exploitation proportion, i.e., the number of repeat or self-citations (exploitation) divided by the total number of citations. A patent is exploitative if its exploitation proportion equals 1; in other words, an exploitative innovation builds solely on the firm's existing knowledge. The last step assesses the proportion of exploitative patents in total patents, year by year, to capture the firm's innovation direction.

For all the dependent variables, year of application captures the precise timing of innovation creation (Yang et al., 2010). To account for the lagged effect of standard participation, and reduce concerns related to reverse causality, all the dependent variables are lagged by one year. Also, since the majority of sample firms are diversified firms, patents not related to ICT were removed using the OECD guidelines.[11]

4.2 Measurement: Explanatory Variables

[11] "Guide to Measuring the Information Society, 2009," published under the responsibility of the Secretary-General of the OECD.

Standard participation. Standard participation is defined according to the disclosure data - typically a letter or e-mail indicating that a firm owns (or may own) IP that is relevant to a proposed standard. Specifically, a firm is said to participate in the standard in a given year if the firm has made a disclosure on any standard in that given year. The extent of standard participation is measured by the number of the firm's disclosures, year by year. There are a few concerns related to disclosure data: (1) disclosure letters are made by patent holders and there is no external validation of the disclosed information (which might create a "false positive"), (2) there is no guarantee that all essential patents are accurately declared (which might create a "false negative"), and (3) it is not possible to identify how critical a firm's technologies are to the standard. Current disclosure policy and SSOs licensing policy effectively reduces the likelihood of over-claiming or under-claiming. Over-claiming is impractical since tracking the commitment made in a disclosure letter is part of the ex-post licensing negotiation. Under-claiming can be costly because the firm could risk losing valuable patent rights, as demonstrated in the Dell consent decree and Rambus cases. The limitations related to use of disclosure data are acknowledged while also emphasizing that disclosure letters provide a unique window on the standards activities of firms, and have been used in a number of studies (e.g., Bekkers et al., 2011; Leiponen, 2008; Pohlmann, 2012; Rysman & Simcoe, 2008; Simcoe et al., 2009).

4.3 Measurement: Control Variables

To minimize alternative explanations and isolate the marginal effects of standard participation, I control for several firm-level determinants of innovation.

R&D intensity. R&D intensity, which is measures as the ratio of R&D investment to annual sales, is a critical measure of the firm's innovation inputs and an indirect proxy for technological opportunities (Ziedonis, 2004).

Firm size. Firm size can have both positive and negative effects on firm innovation (Teece, 1992) and is controlled for using the logarithm of employment.

Firm slack. The availability of excess resources can influence the direction of innovation towards exploration (Singh, 1986) and can have a positive impact on innovation performance (Nohria & Gulati, 1996). Firm slack is calculated as current assets over current liabilities.

Year dummies. A year fixed-effect is included to control for general time trends.

Exploitation evolution index. An exploitation evolution index is calculated for each firm-year based on the weighted share of exploitative innovation of each firm in each technological class in order to control for the influence of technology life cycle.

Patent rate is controlled for when I analyzing the amount of new external knowledge and the share of exploitative innovation. Table 1 provides descriptive statistics and correlations for all main variables. The average ICT firm in the data set made 1.09 disclosures per year and produced 158 patents per year during the study period. Note that standard participation, as expected, is positively associated with patent rate, amount of new external knowledge and share of exploitative innovation. Note also that the correlation between patent rate and amount of new external knowledge is very high (0.9393), suggesting that both measures are likely capturing the same construct.

4.4 Econometric Approach

To address H1 and H2, I conduct a statistical analysis to characterize the relationship between firms' standard participation and change in innovation performance related to innovation rate and share of exploitative innovation. To allow for a curvilinear relationship between standard participation and innovation performance, the squared term of standard participation is included in the regression. I estimate the following equations:

$$\text{Innovation performance}_{i,t} = f(\beta_0 \, SP_{i,t-1} + \gamma \, Z_{i,\,t-1} + \mu_i) \qquad (1)$$

$$\text{Innovation performance}_{i,t} = f(\beta_0' SP_{i,t-1} + \beta_1' SP_{i,t-1}^2 + \gamma Z_{i,t-1} + \mu_i) \quad (2)$$

where $SP_{i,t-1}$ denotes standard participation, which is a continuous variable, and $Z_{i,t-1}$ is a vector of the time-varying control variables.

H3 and H4 refer to the effect difference of standard participation on innovation performance for different levels of R&D intensity. For the non-linear models (negative binomial and panel generalized estimation equation - GEE), I conduct a split-sample analysis to estimate effect differences. The hypotheses were tested based on the following estimation equations:

$$\text{Innovation rate}_{i,t}(SP_{i,t-1}|\text{High R\&D}_{i,t-1}=0) - \text{Innovation rate}_{i,t}(SP_{i,t-1}|\text{High R\&D}_{i,t-1}=1) < 0 \quad (3)$$

$$\text{Share of exploitative innovation}_{i,t}(SP_{i,t-1}|\text{High R\&D}_{i,t-1}=1) - \text{Share of exploitative innovation}_{i,t}(SP_{i,t-1}|\text{High R\&D}_{i,t-1}=0) > 0 \quad (4)$$

where $\text{High R\&D}_{i,t-1}$ is a binary variable indicating whether firm i has higher R&D intensity than the population mean in year t-1.

For the linear model (panel OLS), I test for the effect difference using an interaction term, SP*R&D intensity. H4 is supported if the coefficient for the interaction term is negative and statistically significant. I estimate the following equation:

$$\text{Share of exploitative innovation}_{i,t} = f(\beta_0 SP_{i,t-1} + \beta_1 SP*R\&D + \gamma Z_{i,t-1} + \mu_i) \quad (5)$$

To estimate the rate of innovation (both patenting rate and amount of new external knowledge), I estimate a panel negative binomial regression with firm fixed effects and year controls. The theoretical justification for a fixed-effects model is the need to control for time-invariant unobserved heterogeneity, such as innovation capability which is associated with both innovation performance and standard-setting participation. In addition to the theoretical argument,

there are several empirical reasons supporting use of a fixed effects model. First, since the rate of innovation is a non-negative, integer count variable with overdispersion this suggests use of a panel negative binomial regression. Second, the panel design of this study meets the requirements of a fixed-effects model for three types of controls: (1) those that vary over time for firms, and are different across firms (e.g., R&D intensity and firm slack), (2) those that vary over time but are generally invariant across firms (year dummies), (3) those that are relatively invariant within a firm and over time but vary across firms (firm fixed effects) (Hsiao 1986, c.f., Benner & Tushman, 2002). Third, Hausman tests (chi2(14) = 111.50, Prob>chi2=0.000 for patent rate models; and chi2(15)=97.76, Prob>chi2=0.000 for new external knowledge models) reject a random-effects estimator in favor of a fixed-effects estimator. Thus, a negative binomial panel regression with firm fixed effects and year controls is suitable for estimating rate of innovation.

A panel GEE with logit link function and computed robust errors is used to estimate the direction of innovation (share of exploitative innovation), which is a proportion ranging between 0 and 1 (Papke & Wooldridge, 2008). GEE methods are frequently used to estimate fractional response variables. Papke and Wooldridge (2008) compare panel GEE with the traditional approach of log-odds transformation of fractional response variables and conclude that panel GEE takes account of the bounded nature of the fractional response variables and is more appropriate. However, the regression coefficients of the GEE model provide information on the firm population ("population-averaged") rather than the response of a specific firm to changes in the covariates (Zeger, Liang, & Albert, 1988). Another limitation of the GEE model is that the interaction effect is not straightforward in non-linear models. To control for time-invariant unobserved firm heterogeneity and to investigate the interaction effect, I use fixed effects linear regression models. A linear regression model can predict probabilities outside the 0-1 interval; this model can still

provide useful approximations of the underlying relationship of interest so long as it is not used for predictions too far beyond the sample period.

During the sample period, 14 firms consistently contributed technologies to standards. The remaining firms varied between being participants and non-participants (switchers) - once or multiple times. In order to reduce sample selection bias, I use the switchers subsample to estimate Equations (1) to (5). Regression analysis based on the full sample was used as a robustness check.

5. Results

Table 1 reports the descriptive statistics and correlation matrix. Tables 2–5 present the regression results. Table 2 reports the regression results related to H1, the inverted U-shaped effect of standard participation on the rate of innovation. Models 1 and 3 include control variables and standard participation. Models 2 and 4 introduce the squared term of standard participation. This variable was mean centered before creating the squared term to reduce the multicollinearity. For the effects of the control variables, it seems that larger ICT firms produce more patents, also firms with more available slack show a higher propensity to patent. These results are consistent previous studies (e.g., Yang et al., 2010; Ziedonis, 2004). R&D intensity was found not to affect the patent rate significantly, which might be because R&D intensity is normalized by sales (note the negative correlation between firm size and R&D intensity).[12] Regarding the amount of new external knowledge, large firms and firms with high patent rates assimilate and integrate more new external knowledge.

For the explanatory variable, SP – standards participation, Model 2 and Model 4 provide some support for an inverted U-shaped relationship; the first-order term is positive and significant ($p<0.00$) and the second-order term is negative and significant ($p<0.05$). The turning points at which the innovation rate is maximized for both models (10 for Model 2 and 7 for Model 4) are

[12] I tested the effect of absolute R&D investment on the patent rate, which was positive and significant.

well within the data range. Although the models predict an inverted U-shaped relationship between standard participation and rate of innovation, a negative and significant squared term suggests decreasing returns. In order to investigate whether the downward bend of the curve is statistically significant, I compute the marginal effects for the models by setting SP at the tipping point – (tipping point - 1std), (tipping point - 2std), (tipping point + 1std) and (tipping point + 2std) – with the other variables at their means. The marginal effects analysis results mirror the findings from the previous models –an inverted U-shaped effect of standard participation on the innovation rate and a positive effect on the innovation direction although the marginal effects on the innovation rate are small. Appendix 1 reports the results for the marginal effects. To sum up, the analyses support an inverted U-shaped relationship between standard participation and innovation rate, which confirms H1.

Table 3 reports the regression results related to H2. I expect standard participation to increase the share of the firm's exploitative innovation. In addition to the control variables included in the previous model, patent rate is added as an additional control because previous studies show that it has an impact on the direction of innovation (e.g., Rosenkopf & Nerkar, 2001). Models 5 and 6 are the regression results for the panel GEE; Models 7 and 8 are the panel OLS models with firm fixed effects. Both Models 5 and 7 show a positive relationship between standard participation and share of exploitative innovation ($p<0.05$), confirming H2. Models 6 and 8 include the second-order term of SP. When the second-order term of standards participation is added to both models, the first-order terms become insignificant while the second-order terms are also insignificant. Thus, both the panel GEE and the panel OLS support a positive linear relationship between standards participation and share of exploitative innovation. Therefore, analysis of the share of exploitative innovation is based on the first-order term of standards participation only.

Table 4 reports the results of the regressions testing H3 that high R&D intensive firms are more subject to a concave relationship between standard participation and innovation rate than low R&D intensive firms. The split-sample analyses of patent rates show that for the high R&D intensity group the relationship between standard participation and innovation rate is an inverted U shape; for the low R&D group the relationship is positive. The split sample analyses of amount of new external knowledge show a negative and significant ($p<0.05$) effect of standard participation for the high R&D group, and a decreasing positive effect of standard participation for the low R&D intensive group. Although the regression results of the two measures of innovation rate differ, they provide consistent support for H3, which suggests that low R&D intensive firms benefit more from standard participation than high R&D intensive firms.

Table 5 reports the regression results to test H4 that the relationship between standard participation and share of exploitative innovation is positively moderated by R&D intensity. Models 17 and 18 report the regression results for the split-sample analyses for the panel GEE model. They show that the main effect of standard participation on the share of exploitative innovation remains positive and significant for the high intensity R&D group but insignificant for the low intensity R&D group, which supports H4. Model 19 reports the regression results for the OLS approach. The interaction term is positive but insignificant. Taken together, these results provide some support for H4.

6. Additional Analysis

The observed patterns could be due to spurious correlations caused by a temporal pattern between standard participation and innovation strategy, which would provide an alternative explanation for the observed relationship between standard participation and innovation performance. For example, for direction of innovation, it is possible that the link between standard participation and share of exploitative innovation is due to the evolution of the technology cycle and industry maturity.

Specifically, firms first develop more explorative innovations before the emergence of a dominant design (defined by a standard) (Anderson & Tushman, 1990; Klepper, 1996), then shift to more exploitative innovation when the industry is more focused on commercialization. Year fixed effects are included in the model to account for this. However, year fixed effects may not be fully able to deal with this. For this reason also, innovation performance is investigated one year after standards participation although a shift in the technology life cycle is normally over a much longer time span. Nevertheless, the reservation may persist. Thus, additional analyses are conducted to investigate this particular source of potential bias.

The first analysis involves including additional control variables to capture technology life cycle. The control variable, exploitation evolution index, is constructed in several steps. First, for each technology class (3-digit level), the annual share of exploitative innovation is calculated. Second, the RTA (Revealed Technological Advance) index is used to capture firm's technological structure. The RTA index was proposed by Balassa (1985) and is used frequently "to understand the structural factors underlying the relative technological positions of an economy entity" (Debackere, Verbeek, Luwel, & Zimmermann, 2002: 225). The algebra for RTA is defined as follows:

$$RTA = \frac{Y_{ijt}/\sum_i Y_{ijt}}{\sum_j Y_{ijt}/\sum_i \sum_j Y_{ijt}}$$

where Y_{ijt} is the number of patents of firm i in technological class j at year t. Thus, the numerator represents the percentage share of a given technology class in the firm's total patenting and the denominator represents the percentage share of a given technology class in all technology patents. The value of RTA ranges from 0 to +∞. A value of 1 corresponds to a neutral position, while a value above 1 signifies specialization by the focal firm in the given technology class, and vice versa. To make the index symmetric, I created a "Revealed Symmetric Technological Advance" (RSTA), defined as RSTA= (RTA-1)/(RTA+1), ranging from -1 to +1. The next step consists of calculating the weighted share of exploitative innovation for each firm and each technology class. The

exploitative evolution index for each firm year is obtained by the mean of the weighted share of exploitative innovation. All the regressions are rerun including the exploitative evolution index. The regression results still hold - direction and significance are unchanged, and effect size is similar. The exploitative evolution index is insignificant.

The second additional check involves split sample analysis of technology specialist and technology generalist. The intuition is that if there is a temporal pattern between standard participation and innovation strategy, the temporal pattern will be stronger for technology specialists than for technology generalists since there will be a smaller confounding effect of other technology fields for technology specialists. The variable technology range is used to identify technology specialists and technology generalists. Technology range is the count of the number of unique technology classes to each firm across the sample period. If it is assumed that a firm operates across two technological classes will have wider technological range than a firm operates in one technological class, technology range demonstrates high correlation with firm size as expected. Firms with a technology range above the sample median (13) are categorized as technology generalists, while firms with a technology range below the sample median are technology specialists. The regression is rerun with the two samples and results compared across the two groups. Appendices 2 and 3 show that, in contrast to the predicted temporal pattern, the effects are stronger for with technology generalist group. (Note that the regression for amount of new external knowledge is not reported because one model failed to converge.)

The final additional analysis examines R&D investment post-standard participation. The rationale is that if the firm switches from explorative to exploitative innovation, it will be possible to observe fluctuations in R&D investment post-standard participation since exploitative innovation requires less intensive R&D efforts. I test this proposition by regressing standard participation on R&D intensity; there was no obvious effect of standard participation on R&D intensity. The

supplementary analyses using the existing controls and variable constructs indicate that the results are robust to use of multiple methods to control for temporal effects. The statistics for R&D investment behavior suggest there is not a significant shift in the pattern of investment, which can be taken as evidence supporting the theoretical reasoning underlying the proposed hypotheses, although the possibility of spurious correlations caused by temporal effects cannot be completely ruled out.

7. Discussion and Conclusion

Increasingly, standards and how they are established have become important aspects of innovative firms' business strategies. Firms are viewing standards as "the new guns in global competition" (Egan, 2002), and ICT sector companies are rushing to achieve participation in a wide range of standardization activities, exhibiting a "standards gold rush". These firms are sponsoring and collaborating with numerous standards organizations and releasing hundreds of expert employees to participate in a wide range of standards working groups. They are devoting high-levels of R&D efforts to standards and competing to hire the best standards experts in the industry. This paper extends the literature on the "standards gold rush" by asking how standard participation is related to the innovation performance of participating firms. This is an important question because, on the one hand standard participation requires huge investment of resources by firms, and on the other hand is believed to have long-lasting effects on the firm's future technology path. The empirical tests used a longitudinal data set tracing standard-setting and patenting activities of all public ICT firms over a 10-year period. Taking patents as a measure of innovation, I found that standard participation 1) has an inverted U-shaped relationship with both patent rate and amount of new external knowledge, and 2) has a positive relationship with share of exploitative patenting. I found also that the relationship between standard participation and innovation performance is contingent on firms' R&D intensity. Compared to firms with high R&D investment, less R&D intensive firms show a stronger positive

relationship between standard participation and innovation rate but a weaker positive relationship between standard participation and exploitative innovation.

This study makes several contributions. First, the inverted U-shaped relationship between standard participation and innovation rate suggests that firms can "over-participate" in standards-setting activity because it can have diminishing and ultimately negative returns for innovation development. A possible explanation for the diminishing returns from standard participation on the innovation rate is the detrimental effect of overlapping knowledge. For business managers, this finding points to the critical importance of achieving the right balance between fruitful incoming spillovers and damaging knowledge redundancy. Second, the positive effect of standard participation on the share of exploitative innovation is evidence of the costs of standard participation which need to be weighed against the benefits of standard participation. Finally, the result that high R&D intensive firms benefit less from standard participation in relation to their innovation rates echoes the finding in Blind and Thumm (2004) that companies with a strong technology base stay away from standardization processes because they perceive standardized technologies as less valuable inputs. This finding has significant implications for SSOs; In order to maximize the social benefits of standards, technologically strong firms might require additional incentives to persuade them to contribute their technologies to standards.

While this study extends our understanding of how standard participation is related to the innovation performance of firms, it has some limitations which could be addressed in future studies. First, it is possible that the technology life-cycle might be driving the results. It can be argued that the robustness checks applied in this paper are not a perfect solution; However, in my view, they show that technology life-cycle is unlikely to be the main driver of the detected relationships. Second, thanks to procedural data from SSOs, rich information on standard-setting participation is publicly available. However, it was not possible to link disclosure data to the corresponding

standard, or to identify all corresponding patents using disclosure data, which dictated a firm level study covering different technology fields. To obtain a finer-grained understanding of the phenomenon, the study should be limited to one technology field. Third, this study relies on patents as a measure of innovation. As already mentioned, this could be problematic because patents might be capturing innovation and/or property rights. This problem is not unique to the current study: it occurs in all investigations that use patent data to study innovation. In this study, I try to address this issue by introducing an alternative measure of innovation - amount of new external knowledge. However, this measure is still based on patent data. Further evidence using different methods, samples, and industries is needed to provide further validation of this study's findings.

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Table 1. Descriptive statistics and correlation matrix

	Min.	Max.	Mean	s.d.	1	2	3	4	5	6
1 Patent rate	1	3589	158.53	375.42						
2 Amount of new external knowledge	0	12329	127.30	549.91	0.9393*					
3 Share of exploitative innovation	0	1	0.09	0.16	0.0859*	0.1010*				
4 Standard participation	0	40	1.09	3.06	0.2287*	0.2292*	0.2408*			
5 Firm size	0	13.09	8.27	2.63	0.4691*	0.5061*	0.1546*	0.3591*		
6 Firm slack	0.09	27.63	3.22	3.71	-0.1652*	-0.1803*	-0.0694*	-0.1244*	-0.4262*	
7 R&D intensity	0	0.96	0.16	0.16	-0.1696*	-0.1804*	-0.0199	-0.0873*	-0.4872*	0.2951*

Table 2. Regression analysis of rate of innovation (subsample of switchers)

	(1)	(2)	(3)	(4)
	Patent rate		Amount of new external knowledge	
Standard participation (SP[1])	0.0166* (0.00981)	0.0570*** (0.0188)	-0.0106 (0.00903)	0.0391** (0.0197)
SP squared		-0.00295** (0.00127)		-0.00299** (0.00120)
Patent rate			0.000820*** (0.0000572)	0.000792*** (0.0000576)
Firm size	0.0835*** (0.0237)	0.0795*** (0.0238)	0.272*** (0.0293)	0.263*** (0.0296)
Firm slack	0.0216*** (0.00827)	0.0217*** (0.00827)	0.00246 (0.0126)	0.00161 (0.0126)
R&D intensity	-0.00138 (0.219)	0.00466 (0.218)	0.256 (0.334)	0.224 (0.335)
Year dummies	Yes	Yes	Yes	Yes
_cons	0.760*** (0.229)	0.791*** (0.229)	-2.478*** (0.301)	-2.399*** (0.302)
N	1034	1034	948	948

Note:
1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Table 3. Regression analysis of the share of exploitative innovation (subsample of switchers)

	(5)	(6)	(7)	(8)
	Panel GEE		Panel OLS with FE	
Standard participation (SP[1])	0.0417**	0.0422	0.00494*	0.00398
	(0.0169)	(0.0475)	(0.00299)	(0.00498)
SP squared		-0.0000358		0.0000721
		(0.00207)		(0.000301)
Patent rate	0.000706***	0.000705***	-0.0000456	-0.0000452
	(0.000239)	(0.000252)	(0.0000284)	(0.0000285)
Firm size	0.0192	0.0191	0.0184*	0.0184*
	(0.0439)	(0.0440)	(0.0101)	(0.0101)
Firm slack	-0.0111	-0.0111	-0.00104	-0.00104
	(0.0233)	(0.0233)	(0.00215)	(0.00215)
R&D intensity	0.533	0.532	0.0247	0.0251
	(0.579)	(0.580)	(0.0513)	(0.0513)
Year dummies	Yes	Yes	Yes	Yes
_cons	-3.202***	-3.202***	-0.0910	-0.0909
	(0.459)	(0.461)	(0.0810)	(0.0811)
N	1104	1104	1104	1104

Note:

1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Table 4. Regression analysis of the rate of innovation by R&D intensity (subsample of switchers)

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Patent rate				Amount of new external knowledge			
	High R&D intensity		Low R&D intensity		High R&D intensity		Low R&D intensity	
SP[1]	0.00452	0.122***	0.0364**	0.0308	-0.0261*	0.0198	-0.00463	0.0414*
	(0.0112)	(0.0237)	(0.0165)	(0.0279)	(0.0146)	(0.0326)	(0.0117)	(0.0238)
SP squared		-0.00709***		-0.000644		-0.00252		-0.00264**
		(0.00146)		(0.00255)		(0.00179)		(0.00129)
Patent rate					0.00158***	0.00152***	0.00083***	0.00081***
					(0.000218)	(0.000220)	(0.0000676)	(0.0000683)
Firm size	0.263***	0.284***	0.0170	0.0177	0.387***	0.380***	0.215***	0.203***
	(0.0373)	(0.0374)	(0.0417)	(0.0419)	(0.0467)	(0.0472)	(0.0515)	(0.0517)
Firm slack	0.0235***	0.0235***	-0.0011	-0.0013	0.0114	0.0109	-0.0701*	-0.0701*
	(0.00861)	(0.00856)	(0.0275)	(0.0276)	(0.0118)	(0.0119)	(0.0389)	(0.0384)
R&D intensity	-0.166	-0.233	4.946***	4.926***	0.00364	0.00387	9.379***	9.611***
	(0.241)	(0.238)	(1.624)	(1.626)	(0.0146)	(0.0146)	(1.804)	(1.798)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-0.159	-0.216	1.099*	1.096**	-2.893***	-2.857***	-2.336***	-2.240***
	(0.307)	(0.305)	(0.460)	(0.460)	(0.382)	(0.383)	(0.576)	(0.576)
N	490	490	509	509	456	456	481	481

Note:

1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Table 5. Regression analysis of share of exploitative innovation by R&D intensity (subsample of switchers)

	(17)	(18)	(19)
	Panel GEE		Panel OLS with FE
	High R&D	Low R&D	
Standard participation (SP[1])	0.0441***	0.0397	0.00531
	(0.0167)	(0.0328)	(0.00779)
SP*R&D intensity			0.00142
			(0.0273)
Patent rate	0.000429	0.000842***	-0.0000457
	(0.000434)	(0.000261)	(0.0000284)
Firm size	0.0903*	-0.0174	0.0183*
	(0.0545)	(0.0628)	(0.0102)
Firm slack	-0.0369	0.0328	-0.00104
	(0.0315)	(0.0346)	(0.00215)
R&D intensity	1.145*	2.781	0.0249
	(0.644)	(2.879)	(0.0514)
Year dummies	Yes	Yes	Yes
_cons	-3.495***	-3.266***	-0.0909
	(0.632)	(0.649)	(0.0811)
N	549	555	1104

Note:
1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Appendix 1. Marginal effect

Patent rate			Amount of new external knowledge		
dy/dx	P>z	SP	dy/dx	P>z	SP
.049**	0.002	- 2 std	0.040**	0.041	0
.025**	0.025	- 1std	0.031*	0.070	- 1std
.001	0.928	Tipping point	.001	0.544	Tipping point
-.022	0.304	+ 1std	-.017	0.148	+ 1std
-.046	0.137	+ 2 std	-.041**	0.027	+ 2 std
-.070*	0.086	+ 3std	-.065**	0.016	+ 3std

Note:

1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Appendix 2. Split sample analysis on patent rate

	(1)	(2)	(3)	(4)
	Patent rate			
	Technology specialist		Technology generalist	
Standards participation (SP[1])	0.190	-0.0651	0.0208**	0.0636***
	(0.139)	(0.177)	(0.00982)	(0.0190)
SP squared		0.170**		-0.00309**
		(0.0732)		(0.00127)
Firm size	0.0798	0.0837	0.0834***	0.0775***
	(0.0683)	(0.0686)	(0.0281)	(0.0282)
Firm slack	0.0153	0.0134	0.0390***	0.0390***
	(0.0128)	(0.0128)	(0.0104)	(0.0104)
R&D intensity	-0.372	-0.494	0.188	0.202
	(0.396)	(0.405)	(0.259)	(0.257)
Year dummies	Yes	Yes	Yes	Yes
_cons	0.884*	0.868*	0.754***	0.801***
	(0.480)	(0.482)	(0.283)	(0.283)
N	337	337	697	697

Note:

1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

Appendix 3. Split sample analysis on share of exploitative innovation

	(1) Panel GEE	(2) Panel OLS with FE	(3) Panel GEE	(4) Panel OLS with FE
	Technology specialist		Technology generalist	
Standards participation (SP[1])	-0.0834	-0.0197	0.0419***	0.00437*
	(0.476)	(0.0339)	(0.0158)	(0.00255)
Firm size	0.00705	-0.00162	0.00728	0.0412***
	(0.0905)	(0.0211)	(0.0550)	(0.0114)
Firm slack	-0.0729	-0.000923	0.0189	-0.00235
	(0.0564)	(0.00371)	(0.0267)	(0.00285)
R&D intensity	1.556	0.0779	-0.576	-0.0741
	(0.975)	(0.0973)	(0.654)	(0.0618)
Patent rate	0.00114	0.000000129	0.000567**	-0.0000360
	(0.0226)	(0.00231)	(0.000232)	(0.0000245)
Year dummies	Yes	Yes	Yes	Yes
_cons	-3.197***	0.0193	-2.956***	-0.284***
	(0.909)	(0.133)	(0.544)	(0.102)
N	400	400	704	704

Note:

1. SP: standard participation
2. Standard errors in parentheses
3. * $p<0.10$, ** $p<0.05$, *** $p<0.01$
4. Two-tailed test

CHAPTER FOUR

Understanding Strategic Decision Comprehensiveness – Performance Relationship in New Product Development

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Abstract

In this study we propose and test a theoretical framework for the relationship between strategic decision comprehensiveness (SDC) and new product performance. Arguing that decision quality constitutes a key process outcome that intervenes between SDC and new product performance, we investigated an integrative model of strategic decision processes. Regression analyses using survey data from 149 U.S. manufacturing firms suggest that SDC has a significant positive relationship with decision quality, particularly when competitive uncertainty is low and when customer demand sophistication is high. We also find that decision quality leads to better new product performance when implementation speed is faster. Contrary to our expectation, however, our findings show a negative moderating effect of implementation process complexity on the relationship between decision quality and new product performance.

INTRODUCTION

There is a widely-held belief in the strategic management literature that a firm's economic performance is dependent on the firm's strategic decision processes (Andrews, 1980; Cyert & March, 1963; Eisenhardt, 1989; Rajagopalan, Rasheed, & Datta, 1993). In particular, scholars have paid considerable attention to strategic decision comprehensiveness (herein after SDC), defined as the extent to which decision makers attempt to be exhaustive or inclusive in information processing when making decisions (Fredrickson & Mitchell, 1984: 402). Building on the premise that firms are information processing or interpretation systems that scan and collect data from their environment, interpret the data, and then learn by acting upon the interpretation (Daft & Weick, 1984), this line of inquiry has been argued that SDC is an important process characteristic of effective decision-making (e.g., Dean & Sharfman, 1996; Eisenhardt, 1989; Elbanna & Child, 2007; Judge & Miller, 1991).

In new product development, SDC is especially valuable for firms. Acknowledged as the potential "engine of progress" through which new goods and services can be created, and new markets can be entered, new product development represents a risky and uncertain process by which firms commit resources to future growth. SDC appears to facilitate new product development by increasing new product development speed (Eisenhardt, 1989), reducing effects of cognitive biases associated with new product development, such as escalation of commitment (Miller, 2008), and enhancing managers' confidence to undertake risky pursuits (Eisenhardt, 1989; Heavey *et al.*, 2009).

Despite SDC's merit in new product development, present understanding of its application in new product development is limited to only a few studies (Atuahene-Gima & Li, 2004; Eisenhardt, 1989; Heavey *et al.*, 2009). We note two limitations with the existing literature. First, researchers have suggested that SDC may not be directly related to firm performance and there exist potential intervening variables in the SDC-firm performance

relationship (Forbes, 2007). Yet, few studies have systematically examined how SDC may affect process outcomes and then lead to firm performance. Instead, the existing studies have focused on the effects of SDC on performance (Fredrickson, 1984; Fredrickson & Iaquinto, 1989; Fredrickson & Mitchell, 1984; Priem, Rasheed, & Kotulic, 1995), and recently the effects of SDC on decision effectiveness (Elbanna & Child, 2007). This is problematic, because these sets of effects are not wholly interchangeable and are likely to subject to different moderating factors (Forbes, 2007).

Second, while previous studies in the literature have highlighted strategy formulation, few have considered the implementation aspects of strategies derived from the SDC process. Dean and Sharfman (1996) is an exception. Their study, however, treated implementation quality only as a control rather than as an integrated part of strategic decision making. This is problematic, because strategy formulation and implementation jointly affect performance, thus studies of the strategic decision making and performance relationship should include the implementation variables (Ginsberg & Venkatraman, 1985: 423).

In this paper, we investigate how SDC affects new product development performance. We draw upon Rajagopalan et al.'s (1993) integrative model of strategic decision processes. Based on an extensive review of strategic process literature, Rajagopalan et al. (1993) propose that process characteristics may affect process outcomes and then affects economic outcomes. This is because "[T]he relationships between process characteristics and process outcomes are more direct and are less likely to be confounded by extraneous factors than the relationship between process characteristics and economic outcomes" (Rajagopalan *et al.*, 1993: 369). In this study, by focusing on new product projects we develop and test a theoretical model of SDC-decision quality-new product performance. Our theoretical and empirical endeavors will advance the literature in three ways. First, Eisenhardt's (1989) case analysis of decision making in microcomputer industry highlights the role of SDC in new

product development. Indeed, managers regard SDC as a recognizable and controllable set of behaviors that guide decision making in new product development which requires large resource commitments and long-time horizons (Forbes, 2007; Heavey *et al.*, 2009). However, large sample empirical test of how SDC links to new product performance is still missing. We contribute to the literature by positing and testing an integral model of SDC in new product development.

Second, decision quality as a useful indicator of process outcome has been emphasized in the literature (Rajagopalan *et al.*, 1993: 369; Wooldridge & Floyd, 1990). Decision quality refers to the extent to which the quality of the decisions in the strategy making process is better than expected and better than in previous strategy making (Amason, 1996). We argue that to better understand the SDC-performance relationship it is important to develop a process model by incorporating decision quality as an important process outcome. Further, we follow Atuahene-Gima and Li (2004) and examine how different sources of uncertainties (i.e., uncertainty from competitors such as competitive uncertainty and uncertainty from customers such as customer demand sophistication) may moderate this relationship.

Third, while decision quality will be an important antecedent of new product performance, the effectiveness of decision quality may depend on implementation contexts, an important issue which has not been addressed in the literature. Following suggestions by Bourgeois (1980) and Ginsberg and Venkatraman (1985), we move beyond Rajagopalan et al.'s (1993) model by exploring the possibility that the relationship between decision quality and new product performance will be moderated by firms' implementation speed and implementation process complexity.

We organized the paper into four sections. The first section defines the key concepts and develops hypotheses. The second section outlines the data and describes the model. The next section reports the results and the final section contains the discussion and conclusions.

THEOREY AND HYPOTHESES

Theoretical Development

Strategic management literature has long viewed firms as information processing and interpretation systems that decision makers collect, interpret, and act on information (Daft & Weick, 1984). SDC is part of these information processing and interpretation processes and it reflects the synoptic model of decision making which assumes that decision makers use a rational and proactive process wherein they achieve their goals through extensive information search and environmental assessment activities (Andrews, 1980; Ansoff, 1965). This contrasts with the incremental model which views strategic decision making as an adaptation process in light of experience, which unfolds in small, incremental, tentative steps as a pattern of order emerges (Braybrooke & Lindblom, 1963; Quinn, 1980).

Most SDC studies in the literature have attempted to link SDC directly with firm performance by considering environmental uncertainty conditions. However, two different research streams have emerged in the literature on how SDC affects firm performance under uncertain environments and empirical findings are mixed. Building upon the bounded rationality argument (Cyert & March, 1963), the first research stream argues that because decision makers may have limited cognitive capacity, being exhaustive or inclusive in a variety of decision activities is too onerous in turbulent environment than in stable environment (e.g., Fredrickson, 1984; Fredrickson & Iaquinto, 1989; Fredrickson & Mitchell, 1984). Empirically they found that SDC is negatively related to firm performance in a dynamic environment while it is positively related to firm performance in a stable environment.

In contrast, the second stream contends that SDC offers learning opportunities for decision makers in uncertain environments (Menon *et al.*, 1999). Through being comprehensive, decision makers learn from all aspects of their environment, products, and

decisions, and firms can derive benefits from this learning. Eisenhardt's (1989) case analysis of decision making in the highly turbulent industry suggests that SDC enables decision makers to develop richer and more complex mental maps and make quick and quality decisions, thereby leading to better performance. This view matches Judge and Miller's (1991) finding that in a high-velocity industry the number of alternatives simultaneously considered is positively related to decision speed which then leads to higher firm performance. Similarly, Priem et al. (1995) found that there is a positive relationship between rationality and performance for firms in dynamic environments but no relationship in stable environments.

Given these inconsistent findings, it appears that relating SDC directly to firm performance is problematic for at least two reasons. First, firm-level analyses focus on the extent to which a firm uses SDC process, thus "ignoring the possibility that decision-makers may vary their use of processes among specific decisions" (Hough & White, 2003: 481). Second, the SDC-firm performance relationship is likely to be confounded because the process outcomes of SDC are not incorporated (Forbes, 2007).

To advance the literature, we examine the SDC-performance relationship in the context of new product development. Strategic decision making in new product development involves the design and development of the new product, the determination of marketing objectives and market segments, the allocation of resources and others. For this reason, we examine performance at the project level and define new product performance as the achievement of a combination of market objectives relating to sales, market share, and revenue growth for a new product. By doing so, the peculiarities of each project will be captured (Atuahene-Gima & Li, 2004). More importantly, building upon Rajagopalan et al.'s (1993) integrative model of strategic decision processes, we theorize that SDC in new product development may not directly relate to new product performance. Instead, SDC is more directly linked to process

outcomes such as decision quality. In other words, SDC will affect decision quality and then affects new product performance. Without achieving high quality decisions, SDC may have little value to new product performance.

[Insert Figure 1 about here]

Our theoretical model is generally paralleling with the work by Eisenhardt (1989) and Judge & Miller (1991) which have shown that SDC leads to decision speed which in turn affects firm performance. While decision speed is a critical concern in making comprehensive decisions, we argue that decision quality is equally important in understanding the effect of SDC on performance because it is the quality of strategic decisions that affects firm performance (Amason, 1996: 123; Rajagopalan *et al.*, 1993). Wooldridge and Floyd (1990) demonstrated that decision quality is the process outcome between strategy process (e.g., middle management involvement in strategy) and firm performance. If we acknowledge that SDC offers learning opportunities for decision makers, the learning process may not only imply learning to make fast decisions but also imply learning to make better decisions. As Eisenhardt (1989: 558) argued, "the process of comparing alternatives helps decision makers to ascertain the alternatives' strengths and weaknesses and builds decision makers' confidence that the most viable alternatives have been considered". Indeed, without quality decisions, fast decision making may increase the failure rate of new products. Further, our model differentiates from prior work by including multidimensional environmental uncertainties as moderators between SDC and decision quality as well as implementation factors as moderators between decision quality and new product performance. Thus, our model integrates the two different perspectives of information processing theories as identified earlier.

SDC and Decision Quality: The Moderating Role of Environmental Uncertainty

The relationship between SDC and decision quality in new product development seems to be obvious. From information processing and learning perspectives, when decision makers extensively search information, thoroughly examine multiple explanations for the problems faced and for the opportunities available, carefully attend to one another's perspective and learn from each other, they are more likely to produce a synthesis that is qualitatively superior to the decision which is based on a few alternatives to the status quo. As Amason (1996: 124) argued, decision quality will be best realized through "critical and investigative interaction processes in which team members identify, extract, and synthesize their perspectives to produce a decision." Also, through being comprehensive, decision makers will have more accurate perceptions of environmental conditions before decisions (Fredrickson & Mitchell, 1984). It appears that decision makers who conduct comprehensive analysis will be more confident to develop effective product development plans for reconciling their organizations with environmental reality, thus making high quality decisions (Dean & Sharfman, 1996). Elbanna and Child (2007) provide empirical evidence in support of the positive effect of SDC on decision quality. Using a sample of Egyptian manufacturing companies, they found that SDC has a strong positive effect on decision effectiveness. In contrast, because decision makers from various areas often have different ideas about the product, without comprehensive decision making these members may generally pull the project in different directions and thereby adversely affect the quality of the decisions.

However, the SDC-decision quality relationship is not independent from environmental contexts because the information processing capabilities of new product members will be affected by environmental uncertainty. As discussed earlier, the literature has a debate on the effectiveness of SDC under uncertain environments (e.g., Eisenhardt, 1989; Fredrickson, 1984; Goll & Rasheed, 1997; Priem *et al.*, 1995). To integrate these diverse perspectives, Atuahene-Gima and Li (2004) argued that since managers are information processors,

effective response to environmental uncertainty depends on managerial interpretation of the cause and effect relationships. When decision makers perceive environments as analyzable and they are able to identify correct responses to environmental uncertainty, SDC will be more effective. In other words, the extent to which decision makers can learn and improve their information processing capabilities depends on the sources of environmental uncertainty. While Atuahene-Gima and Li (2004) focused on technology and demand-related uncertainties, in this study we examine environmental uncertainties associated with different stakeholders: competitive uncertainties (i.e., associated with competitors) and customer demand sophistication (i.e., associated with customers). These stakeholder-related uncertainties could be derived from either technology uncertainty, demand uncertainty, or both.

Competitive uncertainty involves significant pace of change, heterogeneity, and unpredictability of competitors' actions (Miller & Friesen, 1983). The high frequency of unexpected and novel changes in competitors' actions makes it difficult for firms to respond with a comprehensive process. We offer three reasons for this argument. First, when competitive uncertainty is high, decision makers require rapid and flexible strategic processes such that they can adapt and improvise to put their best foot forward (Moorman & Miner, 1998). However, SDC is time consuming and less flexible (Forbes, 2007). For this reason, SDC is of little value to decision quality when competitive uncertainty is high.

Second, in a highly competitive environment, firms tend to focus considerable attention on competitors. However, the information about competition is likely to be perceived as low determinate, meaning that the information is susceptible to multiple and contradictory interpretation. Thus, in this environment, managers often assume that competitors possess superior information and imitating others becomes an attractive decision rule (Day & Wensley, 1988; Grewal & Tansuhaj, 2001; Lieberman & Asasa, 2006). Low level of

information determinacy makes it less likely to improve managers' strategic understanding of environment through SDC because collection and analysis of additional information will not help managers to distinguish effective strategies from ineffective ones (Forbes, 2007). This argument is in line with the bounded rationality reasoning which suggests that SDC may be of little value in a highly competitive environment where relationships among key variables are ambiguous and the future is unpredictable (Fredrickson, 1984). Thus, we posit the following hypothesis:

H1. SDC will have a weaker positive relationship with decision quality when competitive uncertainty is high than when it is low.

Customer demand sophistication refers to the extent to which customer requirements relating to product quality, reliability and performance are demanding and sophisticated (LI & Calantone, 1998). Firms have come to accept that meeting the high demands of customers is a fundamental prerequisite for effective competition. Sophisticated customer demand creates uncertainty for firms because it will reduce customer loyalty. A popular press commented on Ford's challenging future that "There once was a time when consumers bought Fords because they always bought Fords, because their parents bought Fords, because their grandparents bought Fords. But these days, consumers are more demanding, more sophisticated and possess little in the way of brand loyalty" (USA Today, 2006: 12A). It appears that when customer demand becomes more sophisticated, it will increase demand uncertainties faced by the firms because of lower customer loyalty. Jaworski and Kohli (1993) have implied that customer demand sophistication will prompt firms to reach out to customers, which will enhance the firms' understanding of uncertainty because customers, particularly lead users, can sometimes articulate their problems and suggest solutions to the firms (Wheelwright & Clark, 1992). SDC helps firms track changes in customer demand and should aid in managing this uncertainty. Atuahene-Gima and Li (2004: 586) argued that uncertainty associated with

customer demands is perceived as more analyzable, making it more amenable to formal search and analysis with rules and criteria for interpretation. Empirically, they found that strategic decision comprehensiveness has a stronger relationship with product quality when demand uncertainty is higher. In light of these arguments and findings, we would expect that integrating diverse information and different perspectives in strategic decision making is of value when customer demand is more sophisticated. In such a condition being comprehensive allows managers to account for every relevant customer problem and requirement, which will lead to high quality decisions. Thus, we posit the following hypothesis:

H2. SDC will have a stronger positive relationship with decision quality when customer demand sophistication is high than when it is low.

Decision Quality and New Product Performance: The Moderating Role of Implementation Factors

Although high quality decisions have the potential to lead to better organizational performance (e.g., Amason, 1996; Wooldridge & Floyd, 1990), empirical studies of this linkage is very limited. Particularly, we are not clear under what conditions this potential can be better realized. Klein and Sorra (1996) have noted that implementation failure is perhaps the most important cause of many organizations' inability to achieve the intended objectives of strategic decision-making. Similarly, Eisenhardt and Zbaracki (1992: 34) have argued that strategy implementation represents one of the organizational conditions likely to have the greatest potential to influence the effectiveness of strategic decision-making. This line of research on strategy implementation suggests that although high quality decisions represent the potential for better new product performance, the extent to which that potential could be best realized depends on how these decisions are implemented. In this study, we advance the literature by examining how implementation speed and implementation process complexity may moderate the relationship between decision quality and new product performance.

Implementation speed is defined as the pace of activities between the time decision makers formulate the strategy and the time they fully deploy it in the marketplace. Implementation speed captures the acceleration of the decision making activities from their conception to their implementation. Because SDC is inherently a slow process, fast implementation enables the early achievement of market advantages in order to put the competitors at a disadvantage (Eisenhardt, 1989; Hambrick, Cho, & Chen, 1996). Implementation speed enhances the positive impact of decision quality on performance by ensuring focused activities and commitment to set goals and allowing the firm to tap quickly into the window of opportunity and to preempt the activities of competitors thereby reaping greater payoffs (Hambrick *et al.*, 1996). For example, Eisenhardt (1989) finds that decision making in the most successful companies is simultaneously fast and comprehensive. Also, if implementation speed is slow, decision quality might not matter so much because the firm has chances to improve the decision and/or correct the decision during the implementation process. In contrast, when implementation speed is fast, "getting things right the first time" becomes paramount. Thus, we expect high quality decisions will be more valuable for improving new product performance when implementation speed is faster.

H3. Decision quality will have a stronger positive relationship with new product performance when implementation speed is fast than when it is slow.

Implementation process complexity refers to the extent to which a strategy requires a complex implementation processes in the form of "extensive reorganization of interdependent procedures and/or the coordination of many skills and multiple departments" (MacMillan, McCaffery, & van Wijk, 1985: 77). When the required implementation process is more complex, firms are prompted to necessitate greater integration of information and skills across different departments because the information and skills required for complex implementation processes may span across numerous individuals and departments. On one hand,

implementation complexity increases the likelihood that firms make mistakes during implementation process, and reduces the positive effects of decision quality. On the other hand, implementation process complexity increases replication difficulties for competitors. The totality of knowledge for complex implementation cannot be easily observed, integrated or understood by competitors. For this reason, Weick (1979: 261) exhorted managers to complicate themselves and warned about the dangers of simplification because it leads to decrements in performance. Further, even if implementation process complexity does not provide lasting barriers to imitation, the logistic problems involved in revising procedures, policies and programs to launch a strategy means that the response time by competitors will be longer (MacMillan *et al.*, 1985: 77; Reed & DeFillippi, 1990). In other words, implementation process complexity offers the firms lead-time that their competitors will take to catch up. It is a window of opportunity where the firms with high quality decisions can build on their competitive advantage. Noticing both arguments, we propose that:

H4. Decision quality will have a stronger positive relationship with new product performance when implementation process complexity is high than when it is low.

METHODS

Sample and Data Collection

Obtaining detailed information about strategic decision-making processes requires primary data collection from key informants (Dean & Sharfman, 1996; Eisenhardt, 1989; Goll & Rasheed, 1997). Accordingly, we tested the hypotheses using data collected through a mail survey of manufacturing firms in the United States. We drew our sample from a mailing list of U.S. manufacturing firms that provided by Thomson Directory. To identify key informants we contacted each firm by phone to seek the cooperation and participation of a knowledgeable key informant. Following similar key informant research in strategy research (e.g., Doty, Glick, & Huber, 1993; Goll & Rasheed, 1997), our objective was to identify the

project manager, the person who was most likely to be knowledgeable about the events and practices concerning the product development process. Project managers tend to be more committed to the project, and have good overview of the project deliberation and characteristics. Hence, they are able to evaluate project activities with candor rather than with a specific functional orientation.

Given our interest in testing the relationship between SDC and new product performance, we limited our sample to firms that have launched new product. We identified 393 companies from a commercial list that met the criteria of having recently introduced a new product and having knowledgeable key informants willing to participate in the study. Due to these restrictions, it is likely that the sample is biased toward successful projects, which should be considered when interpreting the results. With two follow-up reminders, we received 149 usable questionnaires for a response rate of 38 percent. We compared the early and late informants and found no significant differences in the study variables suggesting that nonresponse bias is not a concern (Armstrong & Overton, 1977). All responding project managers held senior positions with 64% listing their job titles as vice presidents or managers of marketing, 11% as product managers, 17% CEOs, and 8% engineering managers.

Following prior research (e.g., Hambrick *et al.*, 1996: 665; Verona, 1999), we defined a product development strategy to the informants as involving the determination of product design and development decisions as well as marketing decisions (in areas such as targeted market segments, promotion, packaging, pricing, and distribution) requiring large resource commitments and long time horizons, which are difficult to reverse in the short term. In cases that the firm has developed more than one new product, we asked the informant to focus on the most recent one. The average size of the project team was 5.66 (s.d. = 3.95). The average market duration for the new product was 17.5 months (s.d. = 15.09).

Measures

Existing measures were used where possible. We interviewed 35 part-time MBA students to pre-test the questionnaire. On the basis of their feedback, we revised the questionnaire. With the exception of new product performance, the scale format for all the measures was 1 = strongly disagree to 5 = strongly agree.

New product performance was measured by three items asking respondents to indicate on a 5-point scale (1 = no extent, 5 = to a great extent) the extent to which the new product has achieved sales, market share, and revenue growth objectives for the new product since launch. These measures are core indicators of customer acceptance of a new product and thus capture the market development objectives of the firm. The reliability coefficient for the scale was 0.84. Although archival performance measures are highly desirable, these measures are usually unavailable at the product level. Subjective performance measures such as those used here have been found effective in prior research in strategic decision-making (e.g., Atuahene-Gima & Li, 2004; Priem *et al.*, 1995). As a validation, we found new product performance measure correlated highly with a single-item, 10-point global measure of the degree to which the overall performance of the new product has met management expectations ($r = .72$, $p < .001$), indicating validity of new product performance measure.

Strategic decision comprehensiveness was measured by a five-item scale borrowed from Miller et al. (1998). We asked the informants to rate the extent to which the strategic decision-making in product development involved the consideration of a large number of alternatives, diverse criteria for evaluating the alternatives, consideration of multiple explanations and examinations of any suggested course of action, and the extensiveness of the search for alternatives. The scale has a reliability coefficient of 0.91.

Decision quality was measured by a three-item scale based on Amason (1996). We asked the respondents to rate the overall quality of the decision, the quality of the decision

relative to its original intent, and the quality of the decision compared with previous decisions. The scale's reliability was 0.86.

Competitive uncertainty was measured by three items which reflected the unpredictability about competitor activities and the product markets. The scale's reliability coefficient was 0.65. We measured *customer demand sophistication* by four items adapted from Li and Calantone (1998). These items reflected the degree to which customers for the new product were more demanding in terms of product quality, reliability, service and support than other customers in the industry. The scale has a reliability coefficient of 0.76.

We measured *implementation speed* with four new items reflecting the degree to which the implementation of the project was timely, faster than previous projects, faster than the planned schedule, and speed of implementation was a critical concern to the organization. The scale has a reliability coefficient of 0.78. We measured *implementation process complexity* by five new items based on the work by MacMillan et al. (1985). The scale items assessed the extent to which the strategy implementation process involved coordination of several technically complex relationships and ideas, significant changes in several organizational systems to implement, required complex organizational processes to implement, required highly specialized and pioneering knowledge to implement, and the content was complex. The scale's reliability was 0.85.

We controlled for a number of variables that may influence new product performance. *Firm size* was measured by the natural logarithm of number of employees. *Team size*, measured by the number of people who the informant determined as having significant influence in the strategic decision-making process, represents the magnitude and diversity of cognitive resources for developing and marketing the new product (Ancona & Caldwell, 1992; Simons, Pelled, & Smith, 1999). *Market duration* of the new product was measured by the number of months the product has been launched in the market. It was controlled for

because it may affect perceptions of quality and performance. Finally, we controlled for types of industries. We categorized industries into four types: the information electronics industry, the pharmaceutical and biotechnology industry, the automobile components and parts industry, and other industries (e.g., textile, footware, and paper). We created three dummy variables with other industry category as the base group.

Data Reliability and Validity

Incomplete recall and retrospective rationalization may confound results of surveys based on executive's recall of past events (Golden, 1992). We used several means to limit confounding the results. First, as mentioned earlier, we were careful to select new product project managers as key informants. We also asked for the level of key informant's involvement in, and knowledge of, the strategic decision-making in the product development process on a 10-point scale. The mean for this scale was 9.0. We found that the informants had worked for their firms for an average of 9.95 years. These data show that the key informants have the requisite expertise to respond to the questionnaire. In this situation, relying on the key informant is appropriate (Kumar, Stern, & Anderson, 1993). Second, as mentioned previously, we focused respondents' attention on the strategic decision-making for the most recent new product. As Miller, Cardinal, and Glick (1997) pointed out, focusing respondents on a recent concrete event is less likely to generate biases due to passage of time. Finally, we motivated informants to provide valid data by assuring them of confidentiality and offering a summary of the results. Most of the respondents requested a summary of the research results. This indicates that the informants were professionally interested in the study. As McGrath (2001) argued, such interest improves the conscientiousness and commitment of informants to provide accurate data.

We conducted a confirmatory factor analysis to assess the convergent and discriminant validity of the multi-item constructs. As presented in the Appendix, results of the

confirmatory factor analysis indicated that the measurement model fits the data well (χ^2 = 369.60, p =.003; χ^2/df = 1.23; goodness-of-fit index (GFI) = 0.84; comparative fit index (CFI) = 0.95; incremental fit index (IFI) = 0.95; root mean square error of approximation (RMSEA) = 0.04) all of which confirmed the unidimensionality of each construct in the model. Convergent validity is observed when the path coefficients from the latent constructs to their corresponding manifest indicators are statistically significant (i.e., $t > 2.0$) (Anderson & Gerbing, 1988). All items loaded significantly on their corresponding latent construct, with the lowest *t*-value being 3.88, thereby providing evidence of convergent validity.

We used two methods to assess discriminant validity. First, because 95% confidence bands around the ϕs did not contain a value of 1, we concluded that the constructs possessed discriminant validity (Anderson & Gerbing, 1988). Second, we conducted a chi-square difference test for all of the multi-item constructs in pairs to see if they were distinct from one another. The process involved collapsing each pair of constructs into a single model and comparing its fit with that of a two-construct model (Anderson & Gerbing, 1988). In every case, a two-factor model had a better fit than a single-factor model, thus supporting the discriminant validity of the constructs.

Finally, we assessed the reliability of the multi-item constructs with Cronbach's alpha. As described earlier, all scales except one had reliabilities greater than the recommended 0.70. The alpha for competitive uncertainty is 0.65, which is generally acceptable for questionnaire scales (Li & Atuahene-Gima, 2002: 480). Considering the face validity of this factor and the strong factor loadings, we believed that it was reasonable to use this factor in the subsequent analysis.

To further verify the reliability and validity of the single informant measures we encouraged the project managers to consult an additional knowledgeable informant to complete the questionnaire. We received 30 questionnaires (20% of the sample) that were

completed by multiple respondents. We found no significant differences in all the study variables between these questionnaires and the 80 percent of questionnaires completed by single informants. We also obtained data independently from 2 project team members from each of two firms and 3 project members from each of four firms, yielding a total of 16 respondents. First, we calculated an interrater agreement score for each variable. This measure ranges from 0 ("no agreement") to 1 (complete agreement). Within-project interrater reliability (r_{WG}) for the study's constructs ranged from .86 to .97, which is well above the required 0.70 threshold of acceptable level of agreement (James, Demaree, & Wolf, 1984). We also used analysis of variance to test the similarity of the within-project responses and between-project responses (Amason, 1996). The results revealed that the between-project variance was significantly greater than the within-project variance for each of the constructs, further suggesting substantial agreement among the within-project respondents.[13]

We also conducted a statistical check for common method variance with the Harman's one-factor test suggested by Podsakoff and Organ (1986). A principal component factor analysis for all measures yielded several factors with eigenvalues greater than 1.0. The indicators of the dependent and independent variables did not load on common factors. This coupled with the fact that the first factor did not account for the majority of the variance suggests that a common method variance does not appear to be a serious concern. Finally, several hypotheses tested in this study involved interaction effects. Several scholars (e.g., Aiken & West, 1991; Doty *et al.*, 1993: 1240; Evans, 1985) have observed that the complex data relationships in predicted interactions are not explained by common method bias because

[13] The r_{WG} and ANOVA *F*-statistics for constructs were as follows: Strategic decision comprehensiveness: 0.93, $F = 3.77$, $p < .05$; Decision quality: 0.97, $F = 2.73$, $p < .10$; New product performance: 0.91, $F = 5.56$, $p < .01$; Implementation speed: 0.86, $F = 5.16$, $p < .05$; Implementation process complexity, 0.91, $F = 7.78$, $p < .001$; Competitive uncertainty: 0.91, $F = 26.83$, $p < .001$; Customer demand sophistication: 0.97, $F = 7.30$, $p < .01$.

respondents cannot guess a researcher's interaction hypotheses. Table 1 provides the descriptive statistics and zero-order correlations for all the variables.

[Insert Table 1 about here]

ANALYSIS AND RESULTS

We used hierarchical moderated regression to test our hypotheses. This procedure allows causal priority to be defined, spurious relationships to be removed, and incremental validity to be determined (Cohen & Cohen, 1983). In the models, we regressed the dependent variable on the control variables and independent variables in model 1 and added the interaction variables in model 2. We mean-centered the independent and moderating variables before creating the interaction terms to reduce multicollinearity (Aiken & West, 1991). The highest variance inflation factor in the regression models was 1.67, indicating that multicollinearity is not a problem.

Table 3 presents the regression results of the effect of SDC on decision quality. We interpret our findings based on the results in model 2. Hypothesis 1 proposes that SDC will have a weaker positive relationship with decision quality when competitive uncertainty is high than when it is low. As shown in model 2, strategic decision comprehensiveness has a significant positive relationship with decision quality ($b=.16$, $p < .05$). However, the interaction term between strategic decision comprehensiveness and competitive uncertainty has a significant negative relationship with decision quality ($b=-.19$, $p <.01$), thus supporting Hypothesis 1. To further explain this finding, we plotted the interaction effect in Figure 2. To create the figure, all variables in model 2 in Table 3 except SDC and competitive uncertainty were constrained to means. SDC and competitive uncertainty took the values of one standard deviation below (i.e., low level) and above the mean (i.e., high level). As shown in Figure 2, when competitive uncertainty is low, SDC has a significant positive relationship with

decision quality. However, when competitive uncertainty is high, this positive relationship becomes non-significant. These findings are consistent with Hypothesis 1.

[Insert Table 3 and Figure 2 about here]

Hypothesis 2 states that SDC will have a stronger positive relationship with decision quality when customer demand sophistication is high than when it is low. This hypothesis is supported ($b=.23$, $p < .05$). To illustrate this finding, we plotted the interaction effect in Figure 3 by following the same procedure as creating Figure 2. Figure 3 indicates that when customer demand sophistication is high, the positive relationship between SDC and decision quality is stronger than when it is low, which is consistent with Hypothesis 2.

Hypothesis 3 posits that decision quality will have a stronger positive relationship with new product performance when implementation speed is faster. This hypothesis is also supported ($b=.33$, $p < .01$). Following the same procedure described above, we plotted the interaction effect in Figure 4. As shown in Figure 4, the positive effect of decision quality on new product performance becomes stronger when implementation speed is fast than when it is slow, thus confirming Hypothesis 3.

Hypothesis 4 suggests that decision quality will have a stronger positive relationship with new product performance when implementation process complexity is high than when it is low. The result is contradictory to our prediction ($b= -.19$, $p <.10$). To further illustrate this finding we follow the same procedure as described above to plot the interaction effect in Figure 5. Figure 5 shows that when implementation process complexity is low decision quality has a stronger positive relationship with new product performance than when implementation process complexity is high. Thus, Hypothesis 4 is refuted.

[Insert Figure 3, 4, and 5 about here]

DISCUSSION

Our objective in this study was to propose and test a theoretical framework about how SDC affects new product development performance. Drawing upon Rajagopalan et al's (1993) integrative model of strategic decision processes, we argued that decision quality constitutes a key process outcome that intervenes between SDC and new product performance. We proposed that different sources of uncertainties (i.e., competitive uncertainty and customer demand sophistication) would moderate the relationship between SDC and decision quality. Further we argued that the relationship between decision quality and new product performance was moderated by firms' implementation speed and implementation process complexity.

Findings of this study generally support our theoretical model and shed new light on how SDC matters for new product performance. Consistent with our hypotheses, we find that SDC has a significant positive relationship with decision quality, particularly when competitive uncertainty is low and when customer demand sophistication is high. We also find that decision quality leads to better new product performance when implementation speed is faster. An unexpected result in this study is the negative moderating effect of implementation process complexity on the relationship between decision quality and new product performance. We hypothesized a positive moderating effect, expecting that when implementation process complexity is higher, decision quality tends to have a stronger positive relationship with new product performance. However, as the results suggest, the opposite may be the case. This finding seems to imply that the value of decision quality can be better appropriated when the strategy implementation requirements are simplistic. Although puzzling, a possible explanation for our result could be that complexity makes the implementation become difficult and time-consuming, which decreases the value of high quality decisions in new product development. Clearly, more research is needed to fully

describe the role of implementation process complexity in the relationship between decision quality and new product performance.

Our research extends and enriches researchers' understanding of the role of SDC in firm performance in a number of ways. First, our model includes both the process outcome (i.e., decision quality) and the economic outcome (i.e., new product performance) simultaneously. Though not explicitly hypothesized, our results show that SDC is directly related to decision quality but not related to new product performance (their correlation is not statistically significant at $p < .05$ level). These results support the notion by several studies (Atuahene-Gima & Li, 2004; Rajagopalan *et al.*, 1993) that it is critical to bring process outcomes in understanding the relationship between SDC and firm performance because by doing so can reduce the potential confounding effects. Our findings are also paralleling with those of Eisenhardt (1989) and Judge and Miller (1991) which have shown that SDC leads to decision speed which in turn affects firm performance. These findings suggest that SDC is important to firm performance because it represents a learning process (Rajagopalan *et al.*, 1993: 374) and will affect decision-based process outcomes (e.g., decision quality and decision speed). It is the decision-based process outcomes that directly contribute to firm performance. Thus, by not including decision-based outcomes, our understanding of the relationship between SDC and firm performance will be incomplete. Therefore, our study provides a reference point for future research on how to theorize the relationship between SDC and firm performance.

We argued that because SDC was designed to reduce environmental uncertainty it would be more conducive for decision quality where the environmental conditions are analyzable and predictable. Our results support this theoretical reasoning by indicating that competitive uncertainty (where conditions are highly unpredictable and cause-effect relationships are ambiguous) negatively moderates the impact of SDC on decision quality while customer demand sophistication (an environment where decision-makers are fairly

aware of the level of reliability and quality demands of customers) positively moderate this relationship. These results also suggest that the practices of formalizing procedures and criteria on which strategic options in a comprehensive strategy process appear to be more effective when the parameters for successful product development are generally known or easy to diagnose and analyze (Fredrickson, 1984; Hough & White, 2003). However, such comprehensive procedures may restrict the sources of information, the evaluation and choice criteria in decision-making in fast changing environments where critical parameters for successful product development are constantly shifting (Brown & Eisenhardt, 1995).

These results refine current contingency theoretical thinking by suggesting that the environment in which a comprehensive strategy is deployed may play a positive or negative moderating role depending on the ability of decision-makers to analyze and understand the sources of uncertainty. This interpretation is consistent with Atuahene-Gima and Li's (2004: 593) argument that "it is not environmental uncertainty per se, but the information-processing demands created by different sources of uncertainty, that are likely to induce the moderation observed" between SDC and performance. By concentrating on overall environmental uncertainty previous research seems to have missed this insight. Thus, we provide a key to unraveling the inconsistent findings in previous studies by demonstrating the utility of examining the differential contingent effects of different sources of environmental uncertainty. In particular, while Atuahene-Gima and Li (2004) has made a distinction between technology uncertainty and demand uncertainty, our study adds to this line of research by showing that environmental uncertainties associated with different stakeholders (e.g., competitors and customers) also play differential roles in the effect of SDC on decision quality.

Our test of the contingent logic between decision quality and new product performance represents a unique contribution to the literature. Without such a test, one would conclude that

decision quality is directly related to new product performance. Our findings suggest that although decision quality has the potential to lead to better new product performance, the extent to which this potential can be realized depends on both implementation speed and implementation process complexity. Our study offers a finer-grained perspective emphasizing that implementation speed and complexity serve as key organizational contextual conditions for appropriating the value of high quality decisions derived from the SDC process (Eisenhardt & Zbaracki, 1992). Thus, our research extends Rajagopalan et al.'s (1993) integrative model of strategic decision processes by including implementation variables as important contextual conditions to understand the linkage between process outcomes and economic outcomes.

For managers, the findings provide evidence that allocating resources to comprehensive strategic decision-making may lead to higher new product performance. However, managers need to be aware of at least two caveats. First, SDC matters in new product development because it may lead to high quality decisions. However, the value of SDC can be realized only when matched with the appropriate competitive uncertainty and customer demand sophistication conditions. Managers may need to sharpen their skills for understanding the market environments in which to undertake and deploy comprehensive strategic decision-making processes. Second, we suggest that managers must devote attention and resources to effective strategy implementation to ensure new product performance. Although SDC may lead to high quality decisions, these high quality decisions do not seem to have much of an effect on new product performance when implementation requirements are complex. Instead, managers should note that fast implementation appears to be critical in enhancing the positive effect of decision quality.

Limitations and Future Research Directions

The first limitation of this study might be common method bias. However, we believe this may not be a serious problem in the current study. In addition to the measures taken in the research design to validate the measures, the statistical test for method variance did not reveal any problems. Common-method bias statistically increases the shared variance among the independent variables, which reduces the chances of detecting moderating effects. Hence, it is unlikely to account for or distort the interaction effects found in this study (Evans, 1985).

A second limitation is the use of single key informants. Few serious critics argue for the abandonment of key informant survey research. Instead, researchers have emphasized means of designing research studies and analyzing the data obtained to improve the validity of such data. As reported previously, a variety of means were adopted in this study to reduce confounding effects and validate the single informant data. Further, we selected the key informants precisely because they were uniquely qualified to report on the variables in the study. As Shortell and Zajac (1990: 828, 829) observed, "using knowledgeable key informants' perceptions of an organization's strategic orientation is a valid approach in measuring strategy". This approach ensures that the most knowledgeable person in each firm provides data, which in turn ensures low variation in informational and motivational biases that could result from the use of multiple informants occupying different positions (Doty *et al.*, 1993: 1210). Third limitation of this study concerns endogeneity. Specifically, one might argue that SDC is endogenous in the sense that a firm targets at high quality decision will choose high level of SDC. Given the limitation of our data, we are unable to eliminate endogeneity bias. Thus, we caution that the variables in this study are related, but we cannot conclude that the relationships are causal. Finally, we used data from a sample of US firms from by a commercial list provider. Hence, the generalizability of results is limited.

In addition to alleviating the limitations of this study, there are other fertile avenues for further research in this domain. First, we examined only two dimensions of the environment

that were particularly pertinent to the current study. Future research might investigate other environmental dimensions (such as technology uncertainty, munificence, complexity) to advance knowledge in this area. A second potential line of future research could be to examine other process mediating variables that may affect the impact of strategic decision-making characteristics on performance. Several opportunities lend themselves including decision process variables such as commitment and satisfaction (Amason, 1996; Hough & White, 2003), decision speed (Eisenhardt, 1989; Judge & Miller, 1991), and decision scope (Hambrick *et al.*, 1996), which should be examined in future research.

Third, our extensive literature review indicates that prior SDC research mainly focuses on firms in North America (see Atuahene-Gima & Li (2004) for an exception). This narrow focus limits our understanding of the role of SDC in firm performance in other contexts. Rajagopalan et al. (1993: 359) have claimed that "at a broader level, strategic decision process research has paid very little attention to the cultural and institutional context within with the organization is embedded." Clearly, these contextual factors have significant implications for the SDC-performance relationship, which should be addressed in future research.

Finally, research suggests that a firm's internal resources and capabilities need to be bundled with social networks of managers to ensure effective performance. This line of reasoning suggests that the contingency view could conceivably incorporate decision-maker's social capital in explaining performance of strategic decision-making. The argument inspired by social capital focuses on "who you know" by taking account of the firm or decision-making team's relationships with external customers, suppliers, and internal stakeholders. From this viewpoint one can argue that the effectiveness of strategic decision-making may depend on the support of these external and internal constituents. This line of research has potential to enrich strategic decision-making research which, we argue, largely views the

process as atomistic and thus deficient in its examination of the role of units external to the focal decision-making group.

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TABLE 1

Correlation Matrix and Descriptive Statistics of Measures

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12
1. New product Performance	5.22	1.02	---											
2. Team size	5.48	3.49	.07	---										
3. Firm size	398.45	1219.82	-.00	.25**	---									
4. Market duration of new product	16.80	14.63	-.06	.20*	-.08	---								
5. Information electronics industry	0.41	0.49	-.11	.13	.02	.08	---							
6. Pharmaceutical and biotechnology industry	0.13	0.33	-.01	-.04	.10	-.02	-.30**	---						
7. Automobile components and parts industry	0.16	0.37	.04	.08	.08	.02	-.38**	-.18*	---					
8. Competitive uncertainty	2.85	0.85	.08	-.03	-.03	-.25**	.12	-.19*	.08	---				
9. Customer Demand sophistication	3.91	0.78	.10	.06	.09	.13	-.02	-.04	.02	.06	---			
10. Strategic decision comprehensiveness	2.93	0.87	.21*	.05	.07	-.13	-.03	-.02	-.02	.08	.07	---		
11. Decision quality	3.67	0.77	.41**	.03	.08	-.03	-.23**	.01	.09	-.04	.23**	.23**	---	
12. Implementation speed	2.94	0.86	.10	.20*	.10	-.05	-.10	.02	.12	.12	.07	.14	.31**	---
13. Implementation process complexity	2.81	0.94	.10	.08	.38**	-.01	-.08	.07	.15	.10	.22**	.25**	.24**	.10

Significance levels: $^{*}p < .05$; $^{**}p < .01$

TABLE 2

Regression Analysis of Strategic Decision Comprehensiveness and Decision Quality [a]

Variables	Decision Quality	
	Model 1	**Model 2**
Control variables		
Constant	2.63 (.46)	2.67 (.45)
Team size	.05 (.02)	.01 (.02)
Firm size	.03 (.04)	.04 (.04)
Market duration of new product	-.00 (.01)	-.00 (.01)
Information electronics	-.42 (.15) **	-.35 (.15) *
Pharmaceutical and biotechnology	-.19 (.22)	-.15 (.22)
Automobile components and parts	-.06 (.19)	-.08 (.19)
Direct effects		
Competitive uncertainty	-.08 (.08)	-.09 (.08)
Customer demand sophistication	.21 (.08) *	.21 (.08) **
Strategic decision comprehensiveness (SDC)	.17 (.07) *	.16 (.07) *
Interaction effects		
SDC X Competitive uncertainty		-.19 (.06) **
SDC X Customer demand sophistication		.23 (.09) *
R^2	.16	.26
Adjusted R^2	.11	.19
F-value	2.72 **	3.90 ***
N	132	132

[a] standard errors are in parentheses.
$^{\dagger}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

TABLE 3

Regression Analysis of Decision Quality and New Product Performance [a]

Variables	New Product Performance	
	Model 1	**Model 2**
Control variables		
Constant	3.41 (.69)	3.42 (.66)
Team size	.03 (.03)	.02 (.03)
Firm size	-.03 (.06)	-.03 (.06)
Market duration of new product	-.01 (.01)	-.01 (.01)
Competitive uncertainty	.13 (.11)	.15 (.11)
Customer demand sophistication	-.04 (.12)	-.07 (.11)
Information electronics	-.15 (.21)	-.19 (.21)
Pharmaceutical and biotechnology	-.07 (.29)	.02 (.29)
Automobile components and parts	.00 (.27)	-.07 (.26)
Direct effects		
Implementation speed	-.12 (.11)	-.08 (.11)
Implementation process complexity	.03 (.11)	.06 (.10)
Decision quality	.56 (.13) ***	.53 (.12) ***
Interaction effects		
Decision quality X Implementation speed		.33 (.11) **
Decision quality X Implementation process complexity		-.19 (.11) †
R^2	.21	.28
Adjusted R^2	.13	.20
F-value	2.74**	3.39***
N	127	127

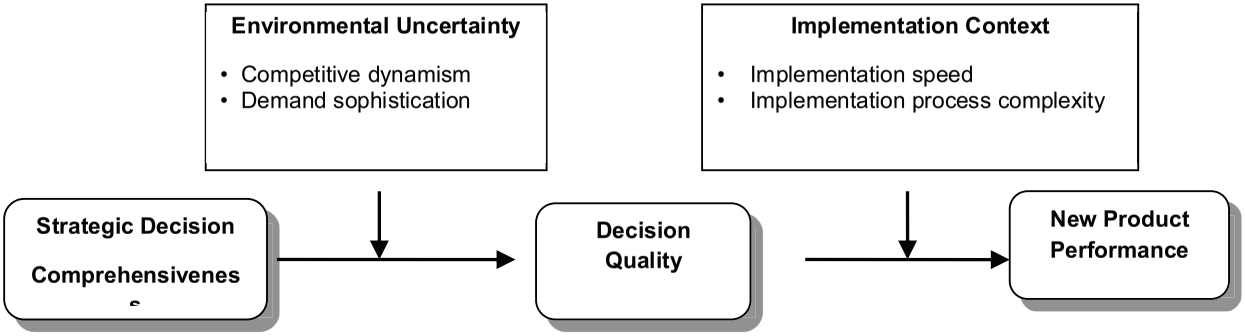
[a] standard errors are in parentheses.
†p < .10; *p < .05; **p < .01; ***p < .001

APPENDIX
Construct Measurement and Confirmatory Factor Analysis Results

Construct Measurement	Standardized Loading	t-value
New Product Performance		
Indicate the extent to which the new product has been achieved the following objectives since launch:		
• Sales growth	0.86	12.50
• Market share	0.80	11.13
• Growth in revenue	0.86	12.46
Competitive Uncertainty		
Indicate your degree of agreement about how well these statements describe the market environment during the new product development.		
• Competitor activities in the market were changing quite rapidly	0.44	4.32
• The product market had many new competitors.	0.37	3.88
• The product market competitive conditions were highly unpredictable.	0.58	6.37
Customer Demand Sophistication		
Indicate your degree of agreement about how well these statements describe the target customers for the new product. The customers were:		
• Demanding for high product quality and reliability.	0.75	9.07
• Sophisticated in terms of product requirements.	0.68	8.19
• Concerned with product service and support.	0.63	7.47
• Concerned with a good fit between their needs and the product offering.	0.61	7.13
Strategic Decision Comprehensiveness		
During the new product development process, to what extent did the team members:		
• Develop many alternative courses of action to achieve the intended objectives?	0.73	9.82
• Conduct multiple examinations of any suggested course of action the team wanted to take?	0.79	11.11
• Thoroughly examine multiple explanations for the problems faced and for the opportunities available?	0.91	13.56
• Search extensively for possible alternative courses of action to take advantage of the opportunities?	0.84	12.01
• Consider many different criteria before deciding on which possible courses of action to take to achieve your intended objectives?	0.71	9.45

Construct Measurement	Standardized Loading	t-value
Decision Quality		
How do you characterize the quality of your major decisions in developing the new product (from Poor to Excellent)?		
• The overall quality of the decisions in the strategy making process	0.81	11.22
• The quality of the decisions relative to the team's original intent	0.83	11.65
• The quality of the decisions compared with that of previous decisions in other new products	0.82	11.46
Implementation Speed		
To what extent do you agree with the following statements about implementing the product and market strategy?		
• The implementation was faster than in other previous strategies.	0.75	8.65
• The implementation was much faster than our planned schedule required.	0.71	8.12
• The strategy was implemented in a shorter time than expected.	0.57	6.22
• Speed of implementation of the strategy was a critical concern of the team.	0.61	6.98
Implementation Process Complexity		
To what extent do you agree with the following statements about the product and market strategy.		
• The strategy implementation involved combination of several technically complex ideas and relationships	0.69	9.03
• The strategy required complex organizational processes to implement	0.81	11.27
• Implementation of the strategy required highly specialized and pioneering knowledge	0.70	9.21
• The strategy content was complex to implement compared with previous ones.	0.84	11.84
• The strategy required changes in several organizational systems to implement	0.60	7.53
Model Fit Index		
χ^2 = 369.60, df.=300 (p =0.003), GFI = 0.84; CFI = 0.95; IFI = 0.95; RMSEA = 0.04		

FIGURE 1
Conceptual Framework



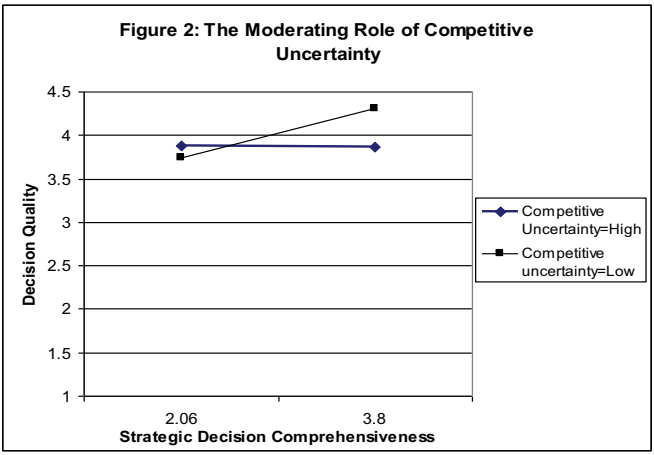


Figure 2: The Moderating Role of Competitive Uncertainty
4.5
4
3.5
3
2.5
2
1.5
1
Decision Quality
2.06
3.8
Strategic Decision Comprehensiveness
Competitive Uncertainty=High
Competitive uncertainty=Low

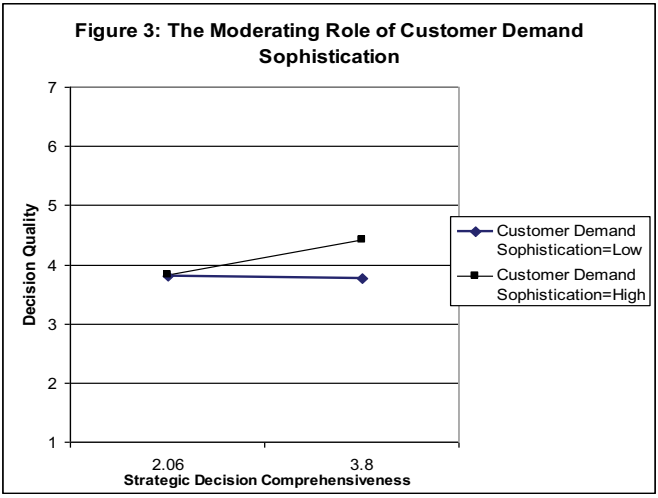


Figure 3: The Moderating Role of Customer Demand Sophistication
7
6
5
4
3
2
1
Decision Quality
2.06
3.8
Strategic Decision Comprehensiveness
Customer Demand Sophistication=Low
Customer Demand Sophistication=High

Figure 4: The Moderating Role of Implementation Speed

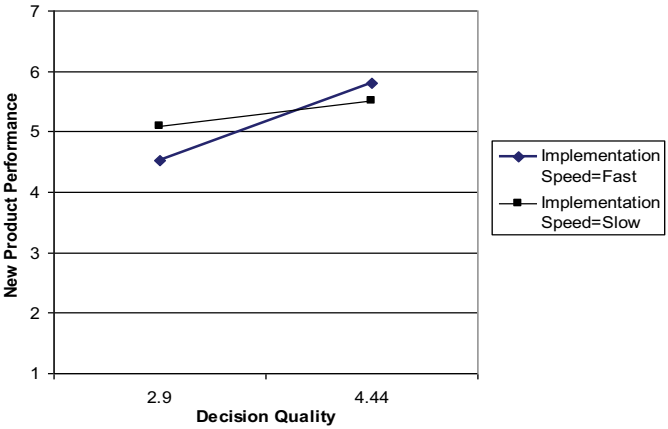
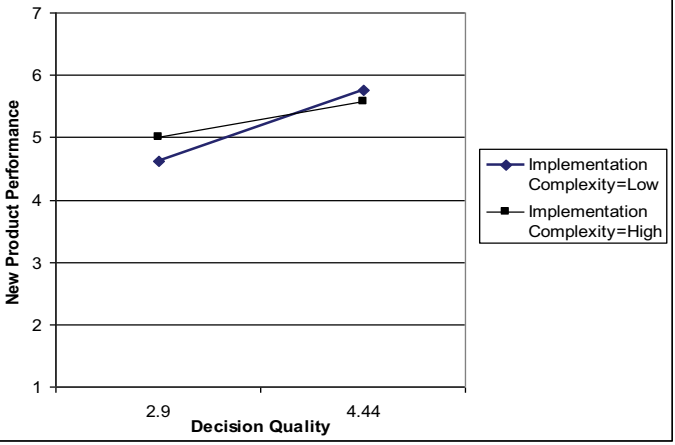


Figure 5: The Moderating Role of Implementation Complexity



CHAPTER FIVE

CONCLUSION

5.1 Introduction

In an environment characterized by continuously increasing rates of change, firms need to innovate in order to stay competitive. Innovation is particularly important for firms' long-term performance and competitiveness (Dutta, Narasimhan, & Rajiv, 2005; Geroski, Machin, & Reenen, 1993; Hall, 2000). In an effort to understand how to foster innovation at firms, extant research has highlighted the role of organizational learning in shaping innovativeness at firms. This PhD dissertation aims to improve our understanding of the complex relationship between organizational learning and innovation capabilities of the firm. Taking a nuanced view of organizational learning, it acknowledges and contributes to the research stream by focusing on three prominent organizational learning processes: ambidextrous learning, learning through knowledge-sharing during standard-setting, and learning by being comprehensive during new product decision making.

5.2 Summary of the Findings and Contributions

5.2.1 Study1: *Learning to Innovate: How Does Ambidextrous Learning Matter to Radical and Incremental Innovation Capabilities?* (with Keld Laursen & Kwaku Atuahene-Gima)

Organizational learning literatures have long argued that organizations capable of ambidextrous learning obtain superior performance and enhance their long term survival. Although "the ambidexterity hypothesis" has been examined and confirmed in various studies (Cao, Gedajlovic, & Zhang, 2009; He & Wong, 2004; Jansen, Simsek, & Cao, 2012; Jansen, Van Den Bosch, & Volberda, 2006), little evidence has been provided on the role played by ambidexterity in building firms' innovation capabilities. Study 1 seeks to address these limitations in the ambidexterity literature by explicitly investigating the effects of ambidextrous learning on radical and incremental innovation capabilities of the firm. Treating ambidexterity as an integral concept, we propose and test a new framework for understanding incremental and radical innovation, i.e., technological discoveries (captured by synergy of ambidexterity) for incremental innovation development and overcoming organizational inertia (captured by balance of ambidexterity) for radical innovation creation. Given that ambidexterity is regarded as an emerging research paradigm in organizational theory (Raisch & Birkinshaw, 2008) and is part of the many prescriptions for firm performance, improvement, and survival (Cao et al., 2009; Gibson & Birkinshaw, 2004; He & Wong, 2004; O'Reilly & Tushman, 2004; Tushman & O'Reilly, 1996), we believe that our attempt would be beneficial to the field and managers. Table 5.1 provides a summary of the hypotheses and results of Study 1.

Table 5.1 Hypotheses and results of Study 1

Hypothesis	Emprical Results
H1a: The combined ambidextrous learning contributes to the firm's incremental innovation capability	Supported
H1b: The combined ambidextrous learning contributes more to the firm's incremental innovation capability than does the balance of ambidextrous learning	Supported
H2a: The balance of ambidextrous learning benefits the firm's radical innovation capability	Supported
H2b: The balance of ambidextrous learning benefits the firm's radical innovation capability more than combined ambidextrous learning	Supported

5.2.2 Study 2: *Standard Gold Rush? A Longitudinal Study of Standard-Setting Participation and Innovation Performance*

The shift towards increasing complexity in modern products has made standards vital important to the ICT sectors. Specifically, ICT firms rely on standard setting organizations (SSOs) for discussing and jointly drafting technical specifications with other firms within the SSOs, and coordinating R&D efforts to create technological solutions or market (Leiponen, 2008; Rysman & Simcoe, 2008). Indeed, a large numbers of innovative technologies, such as GSM, WCDMA, WiFi and MPEG, were developed through joint standardization efforts (Pohlmann, 2012). Hill (1997) argue that firms' ability to contribute their technologies to the dominant standards in their industries, i.e., standards participation, significantly impact their competitive position. Researchers have reported that standard participation increases firms' revenues (Leiponen, 2008),

helps legitimate start-ups (Waguespack & Fleming, 2008) and emerging technologies (Rysman & Simcoe, 2008), and brings competitive advantages (Dokko & Rosenkopf, 2009).

Given the significance of standard participation, there is a wide and intensified interest in influencing standard-setting, a phenomenon termed "standards gold rush". Despite high practical relevance of "standard gold rush", it is still "an important but understudied aspect of technology strategy" (Leiponen 2008). First and foremost, while recent works have focused on how a firm can influence standard-setting for the development of its technologies (Bekkers, Bongard, & Nuvolari, 2011; Leiponen, 2008), there is little empirical work examining whether standard participation enhances or hampers the participating firm's innovation performance. This paper seeks to fill this research gap. My point of departure is that standard participation involves significant investment costs; thus, an important question for both researchers and practitioners is to determine *whether* standard participation enhances or hampers the participating firm's innovation performance, and know how the relationship between standard participation and innovation performance is contingent on firms' characteristics. Table 5.2 provides a summary of the hypotheses and results of Study 2.

Table 5.2 Hypotheses and results of Study 2

Hypothesis	Emprical Result
H1: A firm's extent of standard participation is curvilinearly (taking an inverted U-shape) related to the rate of innovation	Supported

H2: A firm's extent of standard participation is positively related to its subsequent share of exploitative innovation output	Supported
H3: High R&D-intensive firms are more likely than low R&D intensive firms to show a concave relationship between standard participation and the innovation rate.	Supported
H4: The positive relationship between standard participation and share of exploitative innovation output is weaker a firm with a high level of R&D intensity than for a firm with a low level of R&D intensity	Supported

Study 3: *Understanding Strategic Decision Comprehensiveness – Performance Relationship in New Product Development* (with Kwaku Atuahene-Gima & Haiyang Li)

In new product development, strategic decision comprehensiveness (herein after SDC), defined as the extent to which decision makers attempt to be exhaustive or inclusive in information processing when making decisions (Fredrickson & Mitchell, 1984: 402), is argued to be an important process characteristic of effective decision-making. SDC is found to facilitate new product development by increasing new product development speed (Eisenhardt, 1989), reducing effects of cognitive biases associated with new product development, such as escalation of commitment (Miller, 2008), and enhancing managers' confidence to undertake risky pursuits (Eisenhardt, 1989; Heavey, Simsek, Roche, & Kelly, 2009).

Despite SDC's merit in new product development, present understanding of its application in new product development is limited in two ways. First, researchers have suggested that SDC

may not be directly related to firm performance and there exist potential intervening variables in the SDC-firm performance relationship (Forbes, 2007). Yet, few studies have systematically examined how SDC may affect process outcomes and then lead to firm performance. Instead, the existing studies have focused on the effects of SDC on performance (Fredrickson, 1984; Fredrickson & Iaquinto, 1989; Fredrickson & Mitchell, 1984; Priem, Rasheed, & Kotulic, 1995), and recently the effects of SDC on decision effectiveness (Elbanna & Child, 2007). Second, while previous studies in the literature have highlighted strategy formulation, few have considered the implementation aspects of strategies derived from the SDC process. Dean and Sharfman (1996) is an exception. Their study, however, treated implementation quality only as a control rather than as an integrated part of strategic decision making.

This paper refines the relationship between strategic decision comprehensiveness (SDC) and performance. Asking how and when SDC leads to new product performance, we develop an integrative model of strategic decision process, which includes decision quality as the process outcome and performance as the economic outcome. We further investigate how different sources of uncertainty and decision implementation factors can affect the integrative model of SDC. Table 5.3 provides a summary of the hypotheses and results of Study 3.

Table 5.3 Hypotheses and results of Study 3

Hypothesis	Emprical Result
H1: SDC will have a weaker positive relationship with decision quality when competitive uncertainty is high than when it is low.	Supported

H2: SDC will have a stronger positive relationship with decision quality when customer demand sophistication is high than when it is low.	Supported
H3: Decision quality will have a stronger positive relationship with new product performance when implementation speed is fast than when it is slow.	Supported
H4: Decision quality will have a stronger positive relationship with new product performance when implementation process complexity is high than when it is low.	Not supported

5.3 Conclusion and Discussion

In summary, though examining three separate approaches that firms employ to manage organizational learning for innovation creation, the three studies in this dissertation collectively contribute to the understanding of how firms can learn to innovate. Building on the KBV, the three studies of this dissertation show that *what an organization learns*, *from whom an organization learns*, and *how an organization learns* will have impact on firms' innovation performance. Furthermore, taking the nuanced view on organizational learning, the studies in this dissertation also emphasize that there are limitation and boundary conditions for different organizational learning processes. I hope the findings and the approach of this dissertation will benefit future studies in advancing our understanding on how to manage organizational learning for successful innovation creation.

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