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Technologically New Products and Value Creation: An Event Study and the Moderating Effect of Knowledge Characteristics

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CERTIFICATE OF ORIGINALITY

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Abstract

The development of technologically new products (TNPs), in which advanced technology is incorporated in new product development, is crucial for firms to gain competitive advantage. However, extant literature is limited in providing understanding of the relationship between TNPs and their financial implications. Based on a sample of 475 major innovation awards for TNPs between 1987 and 2006 in the U.S., we examine the financial impact of TNPs. We further investigate how the knowledge characteristics of a firm that develops TNPs moderate the relationship between TNPs and financial performance. We examine three types of firm knowledge characteristics, which are firm's absorptive capacity, knowledge impact and knowledge breadth. Our research is based on objective data from COMPUSTAT and the National Bureau of Economic Research (NBER) patent database. We find support for an overall positive impact of TNPs and reveal that the impact of TNPs on financial performance is stronger when firms have higher absorptive capacity and more impactful knowledge. However, knowledge breadth negatively moderates the financial impact of TNPs. Our research supports a knowledge-based view of new product development – firms with higher absorptive capacity, more impactful knowledge but narrower (instead of broader) knowledge base obtain stronger financial returns from products they develop.

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List of Abbreviations

GVKEY	Compustat Permanent Identifier for Companies
KBV	Knowledge-based View of Firm
OM	Operations Management
ROA	Return on Assets
SIC	Standard Industrial Classification
TNPs	Technologically New Products

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Chapter 1 Introduction

1.1 Background of the Study

The development of technologically new products (TNPs) has become one of critical determinants of firms' competitiveness and survival (Han, Kim, & Srivastava, 1998). TNPs incorporate significantly advanced or innovative technologies, and aim to solve an existing or unrecognized problem of users in the market (Garcia & Calantone, 2002). In fact, under the increasingly competitive global manufacturing environment, firms often cannot sustain their leading position if they lack innovativeness for new product development (Song & Parry, 1999). The introduction of TNPs, if successful, enables firms to have substantial differentiation advantages and to appropriate financial returns. However, previous research has suggested that technologically innovative firms do not necessarily outperform other organizations. Technological innovation requires substantial research and development (R&D) budgets, and introducing innovative new products is highly risky (Cooper, 2000; Zahra & Nielsen, 2002). Innovators must face the fact that other firms will imitate their actions, typically earning a share of the profits that is much greater than their initial investment (Chaney, Devinney, & Winer, 1991; Teece, 1986).

As the effect of innovation on performance outcome is debated in the literature, researchers have explored a number of contingency factors that affect the impact of innovative products on financial returns (Hendricks &

Singhal, 1997; Langerak, Hultink, & Robben, 2004; Song & Parry, 1999; Sorescu, Chandy, & Prabhu, 2003). Previous studies have examined the contingency effects based on a marketing perspective, focusing on moderating factors such as marketing proficiency, firm's dominance and product portfolio. Recent research has taken a different perspective by focusing on a firm's own resources, behaviors, and capabilities. According to the knowledge-based view of a firm (KBV) (Kogut & Zander, 1992), firm competencies are stocks of knowledge accumulated over time, difficult for competitors to replicate, and are sources of competitive advantage. The knowledge of a firm is considered an important contingent variable for the competitive outcome of TNPs (Birkinshaw, Nobel, & Ridderstråle, 2002).

1.2 Research Objectives

This study extends previous research on new product development, and directly examines the impact of introducing TNPs on value creation by firms. We further focus on knowledge characteristics as contingent variables for the performance outcome of TNPs. Specifically, we focus on technological knowledge. In our research context, knowledge refers to the result of any form of learning in technology, which reflects the amount of knowledge that a firm has accumulated over time and is embedded in the organization (Wu & Shanley, 2009). We argue that knowledge characteristics in the development of TNPs determine the development of TNPs and products' attributes, innovativeness, rareness, and thus products' competitive advantage. Firms' absorptive capacity, knowledge impact and knowledge breadth in the development of TNPs are likely to be linked with greater appropriation of innovation rents (Langerak et al., 2004; Smith, Collins, & Clark, 2005; Wang & Chen, 2010).

1.3 Main Research Methodology

Event study and Hierarchical Linear Modeling (HLM) are the two major research methods used in this study. Event study is common in research on specific economic event of interest. It is a well-accepted methodology in finance studying. Chaney, Devinney & Winer (1991) applied this method in marketing. Later, Hendricks and Singhal (2008) extend its use to Operations Management. It provides more control on the design, because it can eliminate the effect from other variables. The main idea of event study is to calculate the abnormal returns when the event of interest occurs, and to compare the performance of sample firms with the performance of their matched control firms. Barber and Lyon (1996) conducted an event study of long term performance of firms, and pointed out that it is a powerful tool for examining the long term impact of firm specific events if carefully designed.

Beside the event study method, we apply HLM to investigate the roles of moderating factors. Hierarchical linear modeling is effective in multilevel data structure. Simple linear regression or other similar methods fail to consider this attribute in organizational and TNP research, and it is assumed that all firms are similar and there are no differences across industries. However, we have to consider the structure that is embedded in the industry-firm-year relationship. It would be misleading if we overlook the heterogeneity across firms and industries. Our study includes multilevel data of sample firms, because pre- and post-event returns of TNPs are measured for each firm, and firms are distributed over different industry sectors. HLM is widely used in this type of research because it overcomes statistical weaknesses of traditional methods for analyzing nested data, besides reducing concerns about aggregation bias, and provides a mechanism for directly modeling how a predictor variable measured at one level affects dependent variables at another level (Raudenbush & Bryk, 2002).

Specifically, based on a sample of 475 recipients of major product innovation awards in the U.S., we adopt event study to examine the impact of TNPs on financial performance of firms. We further apply HLM test to investigate how knowledge characteristics of firms that develop TNPs are likely to have a moderating impact on financial returns. We adopt return on assets (ROA) and Tobin's q as financial indicators. R&D expenses and patent data are from the National Bureau of Economic Research (NBER) as measures of knowledge characteristics.

1.4 Findings and Implications

We find that TNPs lead to abnormal increases in ROA and Tobin's q in the first two years of after introduction, and firms that have higher absorptive capacity and knowledge impact obtain higher financial returns from their TNPs. However, firms with a higher knowledge breadth actually obtained lower returns from their innovative products. In contrast to our hypothesis, we found that narrower knowledge actually enables organizations to develop TNPs with stronger competitive advantages. Our research supports a knowledge-based view of new product development – firms with high knowledge absorptive capacity, impactful knowledge and narrow (and perhaps more specialized) knowledge obtain higher financial returns from TNPs they develop.

1.5 Thesis Structure

This thesis is organized as follows,

In Chapter 1, we introduce the TNP development background, research objectives, research methodology and main research findings of this study.

Chapter 2 presents the literature review and hypothesis development. We first review extant studies relevant to TNPs, and establish a link between TNPs and value creation by firms through the theoretical lens of the KBV. We then analyze the importance of knowledge characteristics of firms during TNP development, and propose our hypotheses based on related theories and empirical studies.

Chapter 3 provides details about sample selection and data collection and describes how we identify TNPs and retrieve the date of each TNP introduction. We also address the procedures that we follow to match control firms to each sample firm. In addition, we present the factors that we incorporate in our models, and provide the details of the measures.

Chapter 4 shows the main models we apply in this study. This chapter illustrates how we design event study regarding TNPs' impact on firm value, and HLM test on factors that moderates this impact.

Chapter 5 presents the research findings of both event study and HLM test.

Chapter 6 discusses research findings and their implications in detail. We analyze the impact of TNPs on firm value as well as the moderating effect of firm's knowledge characteristics. We also address implications of our findings for the theory concerning new product development and knowledge management.

Chapter 7 concludes this thesis. We present the main findings, conclusions and implications, and point out the limitations of this study and directions for future research.

Chapter 2 Literature and Hypotheses

We review the literature on TNPs and firm performance, and develop the hypotheses according to extant theories and empirical works in this chapter. The literature has provided some theories and empirical evidence that TNPs could have implications for firms' performance, and that this impact is likely to be contingent on firm's knowledge characteristics.

2.1 The Impact of TNPs on Firm Value

Product innovation and introducing TNPs are widely believed to be key determinants of a firm's competitive advantage, accounting for part of differences in profitability across firms (Ceccagnoli, 2009). Offering products that meet the needs of target customers and commercializing the products more efficiently than competitors put firms in a better position to survive and appropriate higher returns (Nonaka & Takeuchi, 1995).

TNPs differ from other new products in that they have substantially different and new technology and offer benefits that are substantially higher than those available from existing products (Aboulnasr, Narasimhan, Blair, & Chandy, 2008; Chandy & Tellis, 1998). Prior literature view TNPs in terms of both technology advancement and customer benefit. From technological perspective, TNPs are based on differentiated technological characteristics of the product: novel and unique technology that is dissimilar from previously used technology (Dahlin & Behrens, 2005). Meanwhile, from customer's perspective, Langerak, Hultink and Robben (2004) emphasized the newness of the products to the market, as well as the novel set of benefits to customers. In this study, we consider TNPs as new products that possess the two features at the same time (Chandy & Tellis, 1998).

TNP development has significant impact on innovating firms and existing markets. In many ways, TNP development is essential for firms to renew the organizations (Chen, Damanpour, & Reilly, 2010). Dougherty (1992) pointed out that development of TNPs and innovation activities are a primary means of firms' consistent renewal. As for the market as a whole, TNP development can also have the potential for three important effects: market expansion, cannibalization and destabilization (Aboulnasr et al., 2008). The most striking difference between outcomes of TNPs and incremental new products is that TNPs are likely to cause great market expansion and cannibalize the sale of existing products. Including the innovating firm, TNPs reduce the value of existing investments in products in the same category (Chandy & Tellis, 1998; Nijssen, Hillebrand, & Vermeulen, 2005). Similarly, introduction of TNPs can destabilize existing markets. By redefining the product category's benefit space and breaking the market balance, TNPs can render previously dominant products obsolete (Aboulnasr et al., 2008; Anderson & Tushman, 2001).

2.1.1 Challenges in TNP Development

Although TNPs indicate new directions of technology development and have great impact on the industry and markets, the benefits for the innovating firms are still a matter of debate. Considering the destructive impact on existing markets and the potential of a new profit making engine, firms face two main challenges. The first is how the innovating firm can better balance its own resources to create TNPs, and the other is how the innovating firm reacts to competitive responses from the existing markets.

TNPs are deemed risky because there is high uncertainty associated with their outcomes (Sorescu et al., 2003). Specifically, firms can't guarantee that they can succeed in TNPs development. This risk is much higher than that of non-innovative products or incrementally new products. Sorescu, Chandy and Prabhu (2003) identified the risk at two stages: development stage and introduction stage. The first risk is associated with innovation activities and the TNP development. Firms need to dedicate sizable resources to develop TNPs, but there is uncertainty about when and whether the firm's effort will successfully be translated into the ready-for-market breakthroughs and products. And it usually causes the TNP development pioneer to burnout (Min, Kalwani, & Robinson, 2006). The other risk occurs during the stage of introducing the TNPs in the market. Firms don't know how exactly the market will respond to the radical products, and they can't predict how customers will adopt the products. These two kinds of risk impact how a firm moves forward in the competition, since these risks determine firm's capabilities for extracting cash flows from the TNPs.

Even firms that succeed at TNP development face the competitive responses from the market to their radical innovations. Prior literature has demonstrated that there exists knowledge spillover among firms, revealing the knowledge used in TNP development to others (Cassiman & Veugelers, 2002). Developing TNPs that are considered pioneers in the industry and market can be costly. Followers tend to take advantage of the first innovating firm, and imitate the latter's technology or product since imitation is typically less expensive than TNP development (Min et al., 2006). Also, Aboulnasr, Narasimhan, Blair and Chandy (2008) noted that responses to competitive actions (i.e., introduction of TNPs) tend to be reciprocal, and in this case, competitors respond to TNP introduction with development of similar products. This response is especially true when it is prompted by the introduction of highly innovative products.

2.1.2 Mixed Findings on TNPs' Impact on Firm Value

Prior research on the effects of TNPs on firm value provides inconclusive results (Sorescu & Spanjol, 2008). Although technological innovation is widely heralded as one of the most critical assets that engender economic benefits, there is little systematic empirical evidence of this belief in extant literature. Some scholars believe innovative, highly differentiated products provide firms with sustainable competitive advantages. Others, however, claim that less innovative products entail less market uncertainty and have more synergy with existing firm resources and capabilities (Calantone, Harmancioglu, & Droge, 2010), leading to higher profitability. Imitation is typically less expensive than innovation, so early followers have the opportunities for a free ride on the pioneer's investments. Compared to the non-innovative products or existing products, TNPs are often less reliable but more costly when they first appear on the market (Agarwal & Bayus, 2002; Hauser, Tellis, & Griffin, 2006). Research shows that more than 70% of TNPs do not fulfill their initial sales goals and about 50% of new products are considered as a "complete failure" (Delre, Jager, Bijmolt, & Janssen, 2007; Kleinschmidt & Cooper, 1991).

On the other hand, some scholars advocate that radically innovative, highly differentiated products provide firms with sustainable competitive advantages (Calantone et al., 2010). The development of TNPs, which involves both advancement in technology and technical functionality, is likely to greatly increase customer benefits (Atuahene-Gima, 2003; Kleinschmidt & Cooper, 1991; Sorescu et al., 2003). After being introduced in the markets, such new products are likely to offer novel ways of solving problems. As innovating firms attempt to pursue emerging opportunities in the market, TNP development offers a good opportunity to create more value in rapidly changing market environments. Defining radical innovative products in pharmaceutical industry and using a sample of 255 new products introduced by 66 publicly traded firms, Sorescu et al. (2003) found that TNPs have a higher mean value in terms of net present value compared to market breakthrough products (e.g. not based on technology novelty).

The inconclusive results about the impact of TNPs on firm performance require deeper investigation. Sorescu and Spanjol (2008) pointed out that the apparent inconsistencies arise from the unclear definition of TNPs, level analysis and the performance metrics used. This study replicates studies on innovation and new product development, aiming to provide more comprehensive insights about TNPs' impact on firm's long term performance. The difference between this study and prior studies is noteworthy. First, most previous studies have focused on antecedents of breakthroughs in products, and stop at the stage of product development. We go further to examine directly the firm value associated with TNPs after their introduction in the market. Second, there are limited studies in the literature that have used objective data to test the relationship between TNPs and firm performance (Gu, 2005; Sorescu et al., 2003; Xin, Yeung, & Cheng, 2008). Third, we operationalized TNPs' benefits by ROA and Tobin's q, making our results comparable with similar studies in other disciplines. While previous research on new product development focus on the firm input, such as the amount spent on research and development (R&D) and the size of a firms' research department. Some studies measure the number of new products or patents as innovation output. But the initial effort could not necessarily lead to final product, so we center on the new product development output. Following Tellis, Prabhu and Chandy (2009), we use innovation outputs (TNPs) and their commercialization in the markets to determine whether the impact is positive. Forth, study on moderating factors on TNPs' performance is scarce, except that Tellis, Prabhu & Chandy (2009) examined corporate cultures in fostering and supporting TNPs. Our study fulfills the gap in the literature. Fifth, the significant difference between this study and prior studies lies in TNP identification and sample selection. We rely on a new method to collect TNPs sample based on innovativeness of the products. The traditional method in empirical studies has been dominated by survey research (Leiponen & Helfat, 2010). We overcome the limitation of self reporting bias in questionnaire measures (Kuester, Homburg, & Robertson, 1999; Sorescu et al., 2003).

2.1.3 Knowledge-based View of Firms and TNPs

Firms in TNP development engage in knowledge-producing activity (Madhavan & Grover, 1998). The theory about knowledge-based view of firms is related to new product development, especially in the process of radical innovations. Therefore, we can apply KBV in this study and rely on it to discuss TNP development.

The recent development of the knowledge-based view provides a new lens through which we may view and understand the primary rationale for a firm's existence – the creation, transfer and application of knowledge (DeCarolis & Deeds, 1999). The fundamental assumption is that knowledge is the critical input in production and the primary source of a firm's value (Grant, 1996).

Firms that possess uncommon and idiosyncratic stocks of organizational knowledge stand a good chance of generating high value (Ranft & Lord, 2002). Especially, firms' capability to develop new knowledge-based assets can create core competencies and sustain competitive advantage (Kogut & Zander, 1992; Pemberton & Stonehouse, 2000). While there is opinion that knowledge resides at the individual level (Grant, 1996; Simon, 1991), firms play a significant role in integrating knowledge of members and creating collective knowledge by providing a social communities within firms (Henderson & Cockburn, 1994; Kogut & Zander, 1992; Nelson & Winter, 1982; Teece, Pisano, & Shuen, 1997). Meanwhile, there are mainly two kinds of knowledge within a firm, tacit knowledge and explicit knowledge (Madhavan & Grover, 1998). Tacit knowledge implies that knowledge cannot be explicated fully and transferred from one person to another without a long process of apprenticeship. In contrast, explicit knowledge is coded knowledge that is relatively easy to articulate, communicate and transfer between individuals and organizations.

When we apply the KBV theory in the TNP development setting, TNPs involve the exploration of knowledge activity in the firm (Katila & Ahuja, 2002; Miner, Bassoff, & Moorman, 2001). The exploration process reflects that a firm makes a conscious effort to address problems with new approaches and moves away from current organizational routines and knowledge bases. It is different from the exploitation of knowledge activity, which indicates firms use knowledge that is closely related to their existing knowledge bases (Katila & Ahuja, 2002).

The development of TNPs embodies the practice of creation, transfer and application of knowledge of firms. Successful knowledge outcomes and breakthroughs in new product development reflect firms' strong capabilities in technological competition, which is crucial for firms' long term survival (Bansal & Bogner, 2007; Franco, Sarkar, Agarwal, & Echambadi, 2009). This knowledge leading to the TNPs is relatively inaccessible and difficult for potential rivals to imitate before they also invest in this research and introduce similar products. Such firms have technological advantage over their potential rivals in relevant fields because of the differentiation of the product and its utility. As the first mover in the technological race, the advantages include strong brand name and customer preferences (Min et al., 2006). The uniqueness and advanced technology in TNPs should strengthen these advantages in the long term. Accordingly, we predict that the advantages outweigh the potential limitations:

H1: TNPs lead to higher firm performance.

2.2 Moderating Effect of Firms' Knowledge Characteristics

Knowledge characteristics of a firm in the development of TNP process influence product characteristics and subsequently the performance outcome of the TNP in the market. Advanced knowledge of technology may enhance

TNPs' novelty and improve inimitability. Firms have to increase the appropriability in their TNP development (Ceccagnoli, 2009). The new knowledge might spill over to rivals quickly through imitation or substitution, and the innovating firms can’t occupy all the benefits associated with the innovations. Cockburn and Griliches (1988) found that return to innovation is related to appropriability conditions of firms. Normally, methods include patenting, secrecy, exploitation of first-mover advantage, and ownership of specialized complementary assets. Thus, appropriability determines to the extent to which firms can limit other firms from imitating its new products and the capability to enjoy the final return of the innovations.

Literature indicates that firms' knowledge resources can act as a fence that deters the entrance of competition in the same product market. When a firm has high appropriability capability, rivals may have no incentive to invest heavily in similar products, or can not easily develop a similar product or a substitute to compete with the original innovators. Consequently, some knowledge characteristics can maximize the value of market opportunities and inhibit competitive imitation after the introduction (Grant, 1991; Lieberman & Montgomery, 1988).

Besides knowledge exploration, TNPs are also related to exploitation of knowledge by the firm. The process to create TNPs requires firms to recombine existing knowledge (Fleming, 2002; Henderson & Cockburn, 1994; Kogut & Zander, 1992). TNP development involves collaboration and communication within the firm in order to take advantages of the existing knowledge base. Therefore, knowledge characteristics not only lead firms to create new knowledge, but also shape the scope and direction of new exploration of TNPs (Katila & Ahuja, 2002). The various choices of knowledge can lead to varied TNPs and, therefore, different performance, because knowledge assets of a firm represent different alternatives available for the firm in the recombination process (Stuart & Podolny, 1996; Teece et al., 1997).

Specifically, in the process of knowledge combination and integration during TNP development, importance of knowledge characteristics is reflected in a firm's capability to establish and retain competitive advantage over a longer duration of time (Chesbrough & Teece, 1996). Helfat and Raubitschek (2000) argued that creation of TNPs depends on both existing products and the underlying path-dependent knowledge and capabilities of a firm. Firms with rich existing knowledge and strong experience in combining knowledge are able to significantly increase TNPs' novelty in a short time (Nerkar & Roberts, 2004). TNP development faces major uncertainty from product's newness, which is usually negatively associated with development time because it requires firms to consider more design alternatives, new development processes and new marketing channels for TNPs (Meyer & Utterback, 1995). However some knowledge characteristics of firms may help firms to address such uncertainties. During TNP development, some knowledge might help firms exploit and transfer new knowledge to new products, and quickly absorb new external technologies appearing on the market (Becheikh, Landry, & Amara, 2006; Lee, 1995). Furthermore, knowledge characteristics are also suggested to improve the level of TNPs' inimitability in the market. Firms increase their returns on TNPs when they possess related existing knowledge resources because the strategy used to appropriate innovation rents of TNPs is highly dependent on knowledge characteristics of the firms. Following the literature on KBV, we identified three knowledge characteristics that are important in study of firm-level performance, absorptive capacity (Ceccagnoli, 2009; Todorova & Durisin, 2007; Tsai, 2009; Zahra & George, 2002), knowledge impact (Hall, Jaffe, & Trajtenberg, 2001; Liebeskind, 1996; Wiklund & Shepherd, 2003; Winter, 1987) and knowledge breadth (Cohen & Levinthal, 1990; Katila & Ahuja, 2002; Leiponen and Helfat, 2010; McEvily & Chakravarthy, 2002).

2.2.1 Absorptive Capacity

Absorptive capacity refers to the capacity of a firm to value, acquire, assimilate, transform and exploit knowledge from external sources for commercial ends (Cohen & Levinthal, 1990; Todorova & Durisin, 2007; Tsai, 2009; Zahra & George, 2002). It is a dynamic capability of the firm which is embedded in organizational processes. The firm with high absorptive capacity can relatively easily reconfigure its resource base and adapt to changing market conditions (Zahra & George, 2002). Zahra and George (2000) propose that absorptive capacity is closely related to knowledge creation and utilization, and research on this capacity also suggest that it is greatly dependent on its current level of technological knowledge (Cohen & Levinthal, 1990; Kim, 1997, 2001), which in turn is derived from previous and current efforts in internal R&D (e.g., Stock, Greis, & Fischer, 2001; Veugelers, 1997). The efforts of a firm on R&D, and subsequently their absorptive capability, are related to firms' abilities in organizational learning (Cohen & Levinthal, 1990; Stock et al., 2001), particularly in assimilating knowledge from various external information sources (e.g., latest advances from science communities) (Bierly & Chakrabarti, 1996; Millar, Demaid, & Quintas, 1997). High absorptive capability enables technology firms to build a heterogeneous knowledge base and such unique technological knowledge is likely to be transformed into distinctive product attributes.

Firms with a well-established knowledge base in a certain area of technology are in a better position to exploit existing knowledge, converting customer requirements into product characteristics (Tsai, 2009). They have the capability to absorb and combine new technological knowledge with their existing knowledge, leading to additional insights and profundity in new product designs (Ahuja & Lampert, 2001). Studying a sample of 2265 Spanish firms, Escribano, Fosfuri and Tribó (2009) found that absorptive capacity is an important source of competitive advantage in new product development, especially in sectors with turbulent knowledge and when such knowledge is well protected by law. Absorptive capacity also enhances firm's capabilities for collaboration with suppliers and customers and, therefore, increases the benefits gained from alliances in product development (Haeussler, Patzelt, & Zahra, 2010). As a whole, firms with higher absorptive capacity are able to develop their TNPs with higher novelty and inimitability (Stock et al., 2001), leading to stronger competitive advantage. Accordingly, we develop a contingency perspective on the relationship between TNPs and firm performance:

H2: Absorptive capacity positively moderates the relationship between TNP introduction and firm performance.

2.2.2 Knowledge Impact

Knowledge impact refers to the extent to which other firms and organizations value the knowledge created by the focal firm. It has been used to map the development of fields of scientific inquiry (Small & Griffith, 1974) and to estimate the quality of scientific capabilities of firms in specific fields (Healey, Rothman, & Hoch, 1986). Knowledge impact may determine a firm's knowledge-based standing in the industry compared with competitors. It is an important component in knowledge creation and utilization, because it signals how other organizations value the importance and usefulness of the knowledge created by the focal firm (Trajtenberg, 1990). We use forward patent citation analysis to measure knowledge impact of a firm. And forward patent citations, that are, citations made by later patents of a patent previously issued, are indicative traces of the importance of commercial innovations (Hall, Jaffe, & Trajtenberg, 2001). Some researchers have concerns that not all firms patent their innovations and it is hard to obtain the necessary data. Patent study, however, offers a quantitative method to link firm activity to performance, and this stream of research becomes popular on product development, innovation, market share and strategy management. Since patenting is an effective strategy to protect the benefits associated with the innovation and prevents competitors from duplicating the introduced products (Ceccagnoli, 2009), it is relatively common for innovating firms to apply patent in many industries (Ceccagnoli, 2009; De Carolis, 2003; Nerkar & Roberts, 2004). Generally patent information is accessible and it is easy to link patents to applicants, and the patent office in many countries offers plenty of data to the public.

A firm's knowledge impact is likely to positively moderate the relationship between TNPs and competitive advantage (Wiklund & Shepherd, 2003). This is because the impactful knowledge helps the firm improve TNPs' innovativeness vis-à-vis rivals, with less impactful knowledge. Proactive companies with a large number of highly cited patents are more likely to be in the forefront of technology, gaining first-mover advantages, targeting premium market segments, and 'skimming' the market ahead of competitors (Zahra & Covin, 1995). New knowledge production is inherently an uncertain and costly process and valuable knowledge in a certain technology area is distributed unevenly across innovators. The ownership of impactful knowledge can potentially help a firm earn monopoly rents (Liebeskind, 1996; Winter, 1987). It can further help innovating firms reduce costs of project selection and asset management, and obtain a balanced, profitable portfolio of TNPs (Hauser et al., 2006). Trajtenberg (1990) found that social value of technology in computed tomography industry correlates with impactful knowledge in terms of patent citations. As a result, this type of products have more opportunities for differentiation, and hence impact positively on performance (Kleinschmidt & Cooper, 1991).

H3: Knowledge impact of a firm positively moderates the relationship between TNP introduction and firm performance.

2.2.3 Knowledge Breadth

Firms' knowledge breadth reflects the focus of technological and application areas in which firms have expertise (Wu & Shanley, 2009). The knowledge-based literature suggests that breadth in technological knowledge is helpful for technological competence and innovation. The literature tends to support that creating a wide range of knowledge is very important for a company to develop more competitive products. The flexibility associated with broader knowledge helps a firm embrace various technologies, digest them and create distinctive ideas (Cohen & Levinthal, 1990; Katila & Ahuja, 2002). With more innovation objectives and knowledge sources, firms can pursue multiple parallel innovation projects at the same time. Leiponen and Helfat (2010) provide empirical evidence that a firm can have higher chance in successful innovation when it has broader horizons of knowledge source. Cohen and Levinthal (1990) emphasized that a diverse knowledge base increases the effectiveness of exploration of knowledge because it enables the firm to know more related information and better re-frame problems. Besides, firms can benefit from different combinations of its various kinds of knowledge, creating unique knowledge that creates stronger barriers for potential rivals.

More generally, diverse technological knowledge gives the firm greater flexibility and adaptability for responding to rapid technological change (Thomke, 1997; Volberda, 1996). Firms with a wider knowledge breadth can also take advantage of knowledge spillovers that exist across different technological areas, or be able to respond quickly when competitors make advancements (Wiklund & Shepherd, 2003). The reason lies in that these firms are able to re-frame the problems during the TNP development to fulfill varied market demands, through overcoming organizational inertia and avoiding familiar thought patterns and competence traps (Wang & Chen, 2010). As a heterogeneous knowledge base developed based on a wide range of expertise is socially complex, the products developed are subsequently more difficult to imitate (McEvily & Chakravarthy, 2002). The complexity increases the "stickiness" of knowledge to the original innovating firms, and it may slow TNPs' performance replication by obscuring the sources of advanced technology, raising the costs of transfer, and increasing the likelihood of imperfect learning. Such a capability based on board knowledge is the major determinant of sustained competitive advantage when new products are introduced. Accordingly, we develop our last hypothesis:

H4: Knowledge breadth of a firm positively moderates the relationship between TNP introduction and firm performance.

Chapter 3 Methods

3.1 Sample Selection

We identify sample firms with TNPs by focusing product innovation awards in relation to the adoption of new technology. Innovation awards for technology products clearly signal the novelty of the products in terms of technology, ensuring they are really “technologically new”. In particular, such awards are normally given after extensive reviews by technology specialists (Hargadon & Sutton, 1997). We identified more than 20 major technology innovation awards such as *EDN Innovation Awards* and *R&D 100 awards*, and gathered more than 1,000 awarded TNPs from 1987 to 2006.

We need to make sure that a sample firm has sufficient data for our analyses. First, a sample firm must be publicly listed so that financial information is available for our analysis. Second, the sample product needs to have a clearly identifiable date of product introduction. Since technology innovation awards may be given before or after the products are introduced, and our purpose is to analyze the financial impact of TNPs after they were launched, rather than after the awards were given, a specific introduction date is important to us. To obtain the date of introduction, we searched names of products along with the company to look for announcements of product introduction. We were able to identify more than 312 and 320 firms with sufficient data for ROA and Tobin’s q, respectively, for further analyses. The main databases and detailed procedures to select sample firms are presented below,

3.1.1 Description of the Main Databases

Lexis Nexis (Academic), COMPUSTAT database, and patent database from the National Bureau of Economic Research (NBER) are the three main databases used in our study. Lexis Nexis (Academic) provides access to a comprehensive full-text collection of domestic and international news and business information from over 5,600 sources, including the *Business Wire, PR Newswire, Washington Post and USA Today*. It is a well-known research database used by many researchers (Hall, Jaffe, & Trajtenberg, 2005; Miller, 2006; Palepu, 1985). At the same time, COMPUSTAT is the main database from which we extracted accounting and financial data of firms. To measure firm's knowledge characteristics, we aggregated the patent data at firm level.

3.1.2 Detailed Procedures to Select Sample

The most important step is to identify TNPs and sample firms. We collected sample firms through three stages.

First, in order to make sure that products introduced by the firms are technological innovations rather than marginally improved products, we made reference to some journals/magazines and their awards for TNPs, and identified innovating firms and their radically new products. This method is not new in research, and the literature has also adopted similar methods in different contexts (e.g., Hargadon & Sutton, 1997; Sorescu & Spanjol, 2008). For example, Sorecsu and Spanjol (2008) adopted this method and examined products that had won innovativeness awards in the category of consumer packaged goods industry. More importantly, Hargadon and Sutton (1997) suggested that these kinds of technical awards signal the innovativeness of the product and its design. This is because review by outside experts and specialists with access to detailed company and product information improves validity of TNPs. Awards to TNPs are generally given after an extensive examination of product innovativeness, differential characteristics compared to the existing products and potential new technology in the market. This method has significant advantages over the identification of TNPs based on survey or retrospective coding because it can overcome self-report bias and retrospection bias (Sorescu et al., 2003). Thus, this method is considered suitable for our study.

The selection of magazines was based on importance of awards in one industry as well as t*raceability* of records of awarded products and firms. Referring to newspapers and academic papers, we identified 28 major awards, including *EDN Innovation Awards, Best of What's new, Medical Design Excellence Awards, Editors' Choice, R&D 100 awards and so on*. These awards were selected from major journals and magazines*, such as Popular Science Magazine, PC Magazine, Canon Communications LLC, R&D magazine and others.* These awards were usually given annually, after evaluating the products and technology development through the whole year. We carefully examined the nature of these awards, and excluded those not based on technological advancement (e.g., focusing on customer benefits or best sellers).

After retrieving the list of TNPs and innovating firms, we checked whether the companies were publicly listed (in COMPUSTAT) because we had to get all accounting and financial data about firm performance from this database. Importantly, we tagged firms with a unique firm ID, GVKEY[1], from the COMPUSTAT. GVKEY helped us to identify firms, check repeated selection and combine the data from COMPUSTAT, Lexis Nexis (Academic) and NBER patent database.

Third, to verify the date of TNP introduction, we searched for announcements of TNPs in Lexis Nexis (Academic) database. We used keywords, "introduce/unveil/launch/announce/present", and combined firm and product names to search the introduction news. We used the date of the earliest publication of the announcement since this date was the earliest when the public got to know the information. This step further helps evaluate whether the products were significant innovations.

1 COMPUSTAT has several identifiers of firms, such as CUSIPs and Gvkey. The same firm can have multiple CUSIPs but has only one GVKEY. To make the firm identifier time invariant, we use GVKEY to tag our sample.

After the three steps, we further excluded multiple TNPs introduced by the same firm when the time lag between two announcements was less than 4 years. Finally, we identified a 475 firm-year sample of TNPs (see examples in Appendix A). However, further examination of whether the firms had sufficient information about their performance and knowledge characteristics was needed.

3.2 Dependent Variables

To examine the impact of TNPs on financial performance, we focus on Return on assets (ROA), which is an accounting-based measure of value creation. Return on assets (ROA), measured as operating income (before depreciation, interest and taxes) divided by total assets, is the most widely used indicator of financial performance (Guthrie & Datta, 2008), particularly for the manufacturing industry. The formula is as follows:

$$ROA = \frac{Sales - (CGS + SGA)}{AT}$$

where:

CGS – the cost of goods sold,

SGA – administration expenses,

AT – total assets.

We further supplement the accounting-based measurement of ROA by a more forward-looking, market-based financial indicator – Tobin's q. The use of Tobin's q provides an additional measure which indicates the value of TNPs anticipated by investors. Tobin's q captures increases in shareholders' value in the capital market due to unmeasured intangible assets such as reputation, goodwill or other future prospects (Bharadwaj, Bharadwaj, & Konsynski, 1999). We apply the formula of Chung and Pruitt (1994) to calculate Tobin's q. We calculated it by the following formula:

$$Tobin's\ q = \frac{MVE + PS + DEBT}{AT}$$

where:

MVE – the product of a firm's share price and the number of common stock shares outstanding,

PS – the liquidating value of the firm's outstanding preferred stock,

DEBT – the value of the firm's short term liabilities net of its short-term assets plus book value of the firm's long term debt,

AT – the book value of total assets of the firm as replacement costs.

We obtained performance data for four successive years upon and after introduction of the TNP (t to t+3, where t is the year of introduction). This is because a successful TNP not only has an impact on performance in the year of introduction but also for a few years after it is introduced. Previous research shows that technology life cycle in fast-changing industries is about 3-4 years (Deng, Lev, & Narin, 1999; Terwiesch, Loch, & others, 1998). We expect TNP introduction should have an impact on firm performance for about four years. Repeated measures enable us to obtain more reliable performance results.

3.3 Moderating Factors

Moderating factors considered in this study include absorptive capacity (ACAP), knowledge impact (KImpact) and knowledge breadth (KBreadth). Consistent with previous research (Cohen & Levinthal, 1990; Escribano et al., 2009; Stock et al., 2001), we used R&D intensity to indicate absorptive capacity of a firm, because successful integration of external and internal knowledge is highly dependent on firms' research activities on their key competencies (Escribano et al., 2009). As discussed above, absorptive capacity of a firm is greatly dependent on its current level of knowledge of a certain technology (Cohen & Levinthal, 1990; Kim, 1997, 2001), which is in turn derived from previous and current efforts in internal R&D (e.g., Stock et al., 2001; Veugelers, 1997). R&D activities represent a firm's efforts to value, acquire, assimilate, transform and exploit external knowledge for product development, indicating the absorptive capacity of a firm. We took the average of two year R&D expenditures prior to introduction of TNPs divided by two years' average sales.

We adopt firms' patent data to measure firm's knowledge impact and knowledge breadth. Since a patent by definition includes a description of a technical problem and a solution to that problem, patent data gives us a detailed and consistent chronology of how a firm accumulates its knowledge stock. Knowledge impact was measured as follows. We first counted the number of patents that a sample firm had obtained over the preceding five years, prior to introduction of TNPs. We then counted the number of forward citations by other firms within the following two immediately following years after each patent was successfully registered, and then divided the number of citations by the total number of patents (over five years). The two-year period after the patent is successfully registered is considered to be appropriate because citations of a patent usually peak during the early years and then decline steadily (Trajtenberg, 1990). For example, Macro (2007) found that citation frequency in the population is hump-shaped in age and falls after 2-3 years. Our choice of two years is consistent with previous research which measure knowledge impact (e.g., De Carolis, 2003).

Knowledge breadth was measured by the Herfindahl-Hirsehman concentration index (HI) measurement of the number of patent classes in the past five years prior to introduction of the TNP (Prabhu, Chandy, & Ellis, 2005). Following patent classification methods developed by Bessen (2009), there are 37 different major categories of patents. The HI measures whether the patents obtained by a firm are concentrated in a few categories or they are widely distributed over different categories. In fact, concentration in patent categories is widely used in the literature to measure knowledge breadth of a firm (Ahuja & Katila, 2001). The formula is as follows:

$$Knowledge\ Breadth_i = 1 - \sum_{j=1}^{n} p_{ij}^2$$

where:

i – firm i,

j – patent class j,

p – percentage of the number of firm i's patents in patent class j,
n – the total number of patent classes.

3.4 Control Variables

We take some firm-level and industry-level controls in our model. Firm-level controls included firm size, performance prior to TNP introduction (at *t*-1), and control firm's performance change. The industry-level controls include industry R&D intensity and industry concentration, which are industry-specific rather than firm-specific. As mentioned above, we excluded a second innovative award within the four year period after the first award. In other words, we included a second award received by the same firm if it was after the four year period. Our sample of 312 awarded TNPs (for ROA analysis) is taken from 329 different firms. We develop a dummy variable as a control factor to indicate whether a firm has more than one TNP award included in our analysis.

Firm size in this study is taken as the natural logarithm of a firm's total assets. Industry concentration is measured by the Herfindahl index (HI) in terms of sales (in the year before TNP introduction; i.e., year *t*-1). It is taken as the sum of squared market shares of each firm in an industry. The higher the HI value is, the more concentrated is the industry. Finally, industry R&D intensity is taken as the median R&D intensity of an industry.

The use of control group in this research is to minimize the confounding caused by some special factors in a particular industry or by the overall state of the economy at a specific time period (Barber & Lyon, 1996). In order to examine the impact of TNP introduction on firm performance, we adopted event study by selecting appropriate sample-control matched pairs. We matched sample and control pairs based on specific matching criteria to minimize the effects of confounding factors in a particular industry or the effects of the overall state of the economy. Barber and Lyon (1996) suggested that matching pre-event performance is the most critical factor for event studies. They also suggest that matching industry type and 90%-110% pre-event performance create the most appropriate matching groups between sample and control firms. Following Hendricks and Singhal (2008), we matched each sample firm to a portfolio of control firms based on two-digit SIC code and the performance range in the year before the introduction of TNP (t-1). Our sample size was further reduced by 11 and 35, to 301 and 294, respectively, for ROA and Tobin's *q,* as we could find comparable control firms.

Chapter 4 Models

This chapter describes the models employed to address the research questions. Two research methods, event study and hierarchical linear modeling, are used in this study. The background of these methods and the steps in building appropriate models to test hypotheses are described.

4.1 Estimation of Abnormal Performance of TNPs

4.1.1 Event Study

To examine the abnormal operating performance on introducing TNP in markets, we adopted event study methods. The purpose of an event study is to measure the effect of an economic event on the value of a firm. Its rationality lies in that the effect of an event in the marketplace will be reflected in performance indicators of the firm. If any new information resulting from an unexpected event is believed to affect a firm's current and future earnings, the market reaction is triggered as soon as the market learns of the event (Agrawal & Kamakura, 1995). Initially, Fama, Fisher, Jensen and Roll (1969) included event study in their seminal paper on the impact of stock split announcements on stock prices. Now the event study has, in fact, become a standard method of measuring market reaction to some announcements, and it is well accepted and widely used in a variety of disciplines, such as finance, accounting, law, organizational behavior, and businesses strategy (Agrawal & Kamakura, 1995; Binder, 1998). In the field of operations management, event study has become a useful tool to examine the effects of various economic events on firm value, including quality certification (i.e., ISO 9000) (Corbett, Montes-Sancho, & Kirsch, 2005; Lo, Yeung, & Cheng, 2009; Yeung, 2008), delays in product introduction (Hendricks & Singhal, 2008), and new product innovation (Xin et al., 2008).

In this study, we apply event study methodology to TNP introductions, and investigate whether these introductions impact firm's value creation capabilities. Since TNPs result from radical innovations and new product development, market and shareholders usually respond to such announcements. Therefore, when an announcement is made about TNPs, market and shareholders' reaction is immediately reflected in firm's value. Measuring abnormal returns of firms with TNP introduction announcement thus enables us to examine market valuation of financial worth of TNPs.

4.1.2 Measuring Abnormal Returns

We set year -1 (t-1) as the base year, and measured changes over the next four years (t, t+1, t+2, t+3). Year t-1 (the base year) is considered appropriate as it is free from the impact of TNP introduction. We then examine the impact of TNPs for four successive years (t to t+3) after TNP introduction. We determine abnormal performance as the sample post-event performance (i.e., actual performance) minus the expected performance. We estimate expected performance as the sample pre-event performance plus the corresponding change of its control group during that period (Barber & Lyon, 1996). The formulas are as follows:

$$AP_{\mathrm{i,t+d}} = SP_{\mathrm{i,t+d}} - EP_{\mathrm{i,t+d}},$$
$$EP_{\mathrm{i,t+d}} = SP_{\mathrm{i,t+k}} + (CP_{\mathrm{i,t+d}} - CP_{\mathrm{i,t+k}})$$

where:

AP – abnormal performance,

SP – performance of sample firms,

EP – expected performance,

CP – median performance of control firms,

i – sample firm i,

t – year of TNP introduction,

d – ending year of ROA or Tobin's q (d=0,1,2,3),

k – base year of ROA or Tobin's q (k=-1).

4.1.3 *Statistical Analysis of Abnormal Returns*

To control for outliers, all results were reported after symmetrically capping the data at the 2.5% level in each tail. We used the Wilcoxon signed-rank test and paired-sample t-test to examine whether the abnormal returns associated with TNP announcement were significantly above zero. Wilcoxon Signed Rank test is a non-parametric analysis of the median, and it is more valid when abnormal returns are skewed or extreme values exist in the test (Barber & Lyon, 1996; Corbett et al., 2005). Paired-sample t-test, on the other hand, is a parametric analysis of the mean, used in test with normally distributed data. We conducted the two analyses based on one-tailed test of significance, and derived results that we could compare.

4.2 Estimation of the Moderating Effects

4.2.1 Hierarchical Linear Modeling

To evaluate the moderating role of knowledge characteristics on the relationship between TNP innovation and firm performance, we applied Hierarchical Linear Modeling (HLM) in our study. HLM is widely used to study multilevel data (Bloom & Milkovich, 1998; Raudenbush & Bryk, 2002), since it overcomes statistical weaknesses of traditional methods for analyzing nested data, besides reducing concerns about aggregation bias and provides a mechanism for directly modeling how a predictor variable measured at one level affects dependent variables at another level. It has become a useful tool in organizational sciences (Hofmann, 1997; Short, Ketchen JR, Palmer, & Hult, 2007).

HLM's nesting of lower levels within higher levels makes it well suited to investigate hierarchically ordered systems (Hofmann, 1997). Specifically, HLM provides for simultaneous partitioning of variance-covariance components, which allows for estimation of multilevel influences without direct measurement of variables associated with each level. Thus, HLM can be straightforward to investigate relationships within a particular level, as well as relationships between or across levels. The use of HLM offers certain advantages. First, HLM recognizes that individuals of lower level within a higher level system (e.g., repeated measures from different years within a firm and firms within an industry). Also, HLM improves the precision of estimates relative to traditional approaches (Hofmann, 1997; Short et al., 2007). Nested data structures may lead to heteroskedasticity in traditional regression analysis because correlations from a level can be more like “alike” than correlations from different levels.

4.2.2 Models in HLM Test

In this study, repeated measures are nested within firms, which in turn are nested within industries, creating a hierarchical data structure with three levels of random variables. Following Ang, Slaughter, and Ng (2002), we adopt an incremental approach. For each analysis (e.g., for ROA as firm performance), we first specify a null model with no predictor variables, in order to test whether there is significant variation in performance. Next, we specify the base model with all control variables. After that, we include the firm-level moderating variables one by one into the base model. Following is the overall formula for our models:

$$
\begin{aligned}
& \textit{Firm performance}_{\mathrm{tij}} = \\
& \quad \gamma_{00} + \\
& \quad \gamma_{10} \times \textit{Firm size}_{\mathrm{tij}} + \\
& \quad \gamma_{20} \times \textit{Pre-event performance}_{(\mathrm{t}=-1)\mathrm{ij}} + \\
& \quad \gamma_{30} \times \textit{Relative performance change of control firms}_{\mathrm{tij}} + \\
& \quad \gamma_{40} \times \textit{Multiple introductions}_{\mathrm{ij}} + \\
& \quad \gamma_{50} \times \textit{Absorptive capacity}_{\mathrm{ij}} + \\
& \quad \gamma_{60} \times \textit{Knowledge impact}_{\mathrm{ij}} + \\
& \quad \gamma_{70} \times \textit{Knowledge breadth}_{\mathrm{ij}} + \\
& \quad \gamma_{01} \times \textit{Industry concentration}_{\mathrm{tj}} + \\
& \quad \gamma_{02} \times \textit{Industry R\&D intensity}_{\mathrm{tj}} + \\
& \quad \mu_{0\mathrm{j}} + \mu_{1\mathrm{j}} + \mu_{2\mathrm{j}} + \mu_{3\mathrm{j}} + \mu_{4\mathrm{j}} + \mu_{5\mathrm{j}} + \mu_{6\mathrm{j}} + \mu_{7\mathrm{j}} + \epsilon_{\mathrm{ij}}
\end{aligned}
$$

where:

Firm performance$_{tij}$ *– the post-announcement performance of sample firms of firm i at year t.*

t – the number of years after the announcement of TNP.

i – company i.

j – industry j.

Chapter 5 Results

In this chapter, we present the results of tests of our hypotheses. There are two sections of results – event study of TNPs' effects on firm value and HLM test of the moderating effect of knowledge characteristics. In each section, we first show the descriptive statistics of the models, and then present the results.

5.1 Results of Event Study on Abnormal Performance

5.1.1 Results of Matching Sample-Control Pairs

Following Hendricks and Singhal (2008), we matched control firms to sample firms in three stages. First, we matched each sample firm to a portfolio of control firms based on two-digit SIC code and the prior performance range in the year t-1. If no firms were found, we then entered step two and lowered the criteria, matching the performance range using all firms in the same one-digit SIC code. If no firms were found in step two, we then matched performance range without the restriction of industry type in step three. If no control firms were found in step three, we removed the sample firms. Matching results are as follows:

ROA as the performance indicator. In our sample of 475 firms, for 316 firms sufficient data were available for calculating their operating ROA in Year t-1. 312 sample firms were successfully matched with at least one control firm based on the criteria of pre-event ROA and industry type. Of the 316 sample firms, control firms for 306 firms (96.8%) were found in step one, and for 6 additional firms (1.9%) in step two. We couldn't find any control firm for 4 firms. Meanwhile, 283 sample firms (89.6%) found more than five or more control firms, while 9 firms (2.8%) had only one control firm. The average number of control firms for each sample firm was 27.16.

Tobin's Q as the performance indicator. For Tobin's q as the performance indicator, we were able to measure 291 sample firm performance at Year t-1. After matching the sample-control firms, we had 286 sample firms with at least one control firm. We found that 284 sample firms (97.6%) could be matched with control firms in step one, and 2 firms (0.7%) in step two. Five sample firms had no matches. Furthermore, there were 274 sample firms (94.2%) with more than five or more control firms, while 5 firms (1.7%) with only one control firm. On average, each sample firm had 25.33 control firms.

5.1.2 Descriptive Statistics of Event Study

Descriptive statistics of the sample and control firms in the base year (i.e., t-1) are shown in Table 1. The mean and median were 7.671% and 11.860%, respectively, for sample firms' ROA, and 7.576% and 11.990%, respectively, for control firms' ROA. For Tobin's *q*, mean and median of Tobin's q were 2.068 and 1.173, respectively, for sample firms, and 2.044 and 1.188, respectively, for control firms. Performance of sample and control firms in terms of ROA and Tobin's q was very similar before TNP introduction.

Table 1 Descriptive Statistics of Pre-event Data for Sample and Control Firms (Year t-1)

	N	Mean	Median	Min.	Max.	St. dev.
Sample Firms						
Return on Assets (ROA) [a]	312	7.671	11.860	-257.500	42.140	25.004
Tobin's q	286	2.068	1.173	0.099	22.350	2.488
Control firms						
Return on Assets (ROA) [a]	312	7.576	11.990	-263.600	41.840	25.107
Tobin's q	286	2.044	1.188	0.103	22.010	2.445

Note: [a] *in percentage*

Table 2 and Table 3 give a general description of the abnormal ROA and abnormal Tobin's q from year t to year t+3. All mean and median values of abnormal ROA and abnormal Tobin's q were greater than 0. For abnormal ROA, mean values of abnormal performance were generally greater than 0.7% during the four years after TNP introduction. For abnormal Tobin's q, we can see the mean abnormal performances were greater than 0.2.

Table 2 Abnormal ROA Results of the Sample Firms

Abnormal firm performance (observation number)	Mean	Median	Min.	Max.	1st Qu.	3rd Qu.	St. dev.
Year t (294)	0.770	0.460	-25.360	23.270	-2.713	4.575	6.940
Year t+1 (267)	1.589	1.092	-23.100	24.900	-3.063	5.332	7.844
Year t+2 (249)	2.180	1.516	-21.320	28.780	-2.420	5.513	9.103
Year t+3 (217)	0.979	0.640	-31.720	27.640	-3.300	5.775	9.636

Note: Abnormal ROA was measured in percentage

5.1.3 Event Study Results of TNPs

Table 4 reports results of two firm performance indicators with the methods of t-test and Wilcoxon signed-rank. All abnormal returns were measured against the base year t-1. Both t-test and Wilcoxon signed-rank test show that abnormal changes in ROA and Tobin's q were consistently positive and highly significant from t to t+3. In the year of TNP introduction, the mean abnormal increase in ROA was 0.77%, which was highly significant at $p < 0.05$. Mean abnormal ROA increase further rose to 1.59% in the year after TNP introduction (i.e., t+1; $p < 0.01$) and reached 2.18% in the second year after introduction (i.e., t+2; $p <0.01$). However, mean abnormal ROA increase dropped to 0.98% in the third year (i.e., t+3; $p < 0.1$), although statistically it was still significant. WSR tests for the median provided similarly significant results, although the magnitudes were slightly different. Therefore Hypothesis H1 is supported.

Table 3 Abnormal Tobin's q Results of the Sample Firms

Abnormal firm performance (observation number)	Mean	Median	Min.	Max.	1st Qu.	3rd Qu.	St. dev.
Year t (271)	0.235	0.084	-1.579	3.232	-0.183	0.477	0.817
Year t+1 (264)	0.273	0.108	-1.633	3.509	-0.222	0.649	0.921
Year t+2 (249)	0.379	0.105	-1.728	4.673	-0.257	0.730	1.155
Year t+3 (228)	0.203	0. 029	-2.839	4.036	-0.331	0.504	1.074

Table 4 Abnormal Performance Results of Sample Firms

Firm performance	Test Methods	Median/Mean (p-value)			
		t-1 to t	**t-1 to t+1**	**t-1 to t+2**	**t-1 to t+3**
ROA [a]	t-test for the mean	0.770 (0.029)	1.589 (0.005)	2.180 (0.000)	0.979 (0.068)
	Wilcoxon signed rank test for the median	0.460 (0.013)	1.092 (0.038)	1.516 (0.001)	0.640 (0.037)
Tobin's q	t-test for the mean	0.235 (0.000)	0.273 (0.000)	0.379 (0.000)	0.203 (0.002)
	Wilcoxon signed rank test for the median	0.084 (0.000)	0.108 (0.000)	0.105 (0.000)	0.029(0.016)

Note: [a] in percentage for the median and mean

Similarly, TNP introduction leads to significantly higher Tobin's q as the value of the firm as evaluated by investors increases. The abnormal Tobin's q, as compared to control firms, was significantly higher after TNP introduction. In the year of TNP introduction ($p < 0.01$) and the value increased by 0.24. The figure further increased to 0.27 in the year after TNP introduction ($p < 0.01$) and reached 0.38 in the second year ($p < 0.01$). The abnormal Tobin's q dropped slightly in the third year after TNP introduction ($p < 0.01$).

Table 5 Means, Standard Deviations and Correlations for ROA

	Variables	1	2	3	4	5	6	7	8	9
1	**Firm size**	1.000								
2	**Previous performance**	-0.120	1.000							
3	**Change of control firms' performance**	0.002	0.320	1.000						
4	**Multiple introductions**	-0.281	0.018	0.037	1.000					
5	**Industry Concentration**	-0.006	0.075	0.058	0.048	1.000				
6	**Industry R&D intensity**	0.006	-0.067	0.090	-0.028	0.347	1.000			
7	**Absorptive capacity**	0.303	0.456	0.038	-0.062	0.107	-0.028	1.000		
8	**Knowledge Impact**	0.037	-0.120	-0.002	-0.133	0.062	0.118	-0.124	1.000	
9	**Knowledge breadth**	-0.416	0.146	-0.033	-0.179	-0.007	0.033	-0.020	0.206	1.000
	Mean	7.708	11.008	-0.537	0550	0.042	0.094	9.652	1.273	0.711
	SD	2.318	14.356	7.350	0.498	0.018	0.060	8.005	1.062	0.191
	Minimum	1.455	-94.832	-43.291	0.000	0.021	0.003	0.117	0.000	0.000
	Maximum	12.236	42.145	54.510	1.000	0.177	0.391	73.809	10.667	0.942

Note: N=798

5.2 HLM Test Results of Moderating Factors

Descriptive statistics about independent variables for ROA and Tobin's q in HLM test are listed in Tables 5 and 6. As shown in the tables, multicollinearity is not a concern of the study, and there are no high correlations between the variables.

Table 6 Means, Standard Deviations and Correlations for Tobin's q

	Variables	1	2	3	4	5	6	7	8	9
1	**Firm size**	1.000								
2	**Previous performance**	-0.025	1.000							
3	**Change of control firms' performance**	-0.056	0.797	1.000						
4	**Multiple introductions**	-0.253	-0.027	0.023	1.000					
5	**Industry Concentration**	0.073	0.063	0.005	0.026	1.000				
6	**Industry R&D intensity**	0.050	-0.030	-0.004	-0.065	0.561	1.000			
7	**Absorptive capacity**	0.394	-0.059	-0.062	-0.114	0.179	0.083	1.000		
8	**Knowledge Impact**	-0.069	-0.007	0.146	-0.122	0.051	0.151	-0.268	1.000	
9	**Knowledge breadth**	-0.405	0.166	0.112	-0.233	0.003	0.043	-0.003	0.130	1.000
	Mean	7.801	1.934	-0.468	0.577	0.040	0.097	9.173	1.279	0.710
	SD	2.198	2.381	1.739	0.494	0.014	0.058	5.692	0.846	0.000
	Minimum	1.311	0.099	-18.860	0.000	0.021	0.003	0.117	0.042	0.942
	Maximum	12.236	22.353	6.902	1.000	0.164	0.391	37.799	3.915	0.195

Note: N= 766

We conducted HLM estimations for both ROA and Tobin's q as dependent variables. Our purpose is to investigate the moderating effect of technological characteristics on the impact of TNP on firm performance. Table 7 and Table 8 present HLM estimation results. In Table 7, the null model shows that the average ROA for sample firms was 12.221, and there was a significant variance in ROA across firms ($p<0.001$). When incorporating the control variables into the ROA model, both AIC and -2 Log-likelihood indicated that Model 2 had a much better model fitness. The results of Model 2 suggest that as control variables, firm size ($p<0.01$), pre-event ROA ($p<0.001$), control firms' ROA changes ($p<0.01$) and introductions of multiple TNPs by a firm ($p<0.1$) were significant predictors of ROA. With regard to Tobin's q in Table 8, we found that similar to the case of ROA, pre-event Tobin's q and control firms' changes in Tobin's q were significant predictors of post-event Tobin's q of sample firms. However, unlike ROA, firm size and introductions of multiple TNPs by a firm were not significantly related to Tobin's q. Instead, some industrial level control variables, including industry concentration and industry R&D, are significant control factors.

For Model 3A to 3C in HLM estimations, we included absorptive capacity, knowledge impact and knowledge breadth one by one into the models. In Model 3D, we included all the three moderating factors in a model. Our results showed that as we included the moderating factors, values of both AIC and -2 Log-likelihood decreased significantly (Chi-square > 3.84 for change of 1 *df*; $p < 0.05$), indicating a significantly better fit of model was obtained as we included any one of these three moderating factors.

Table 7 HLM Estimation for ROA

	Model 1	Model 2	Model 3A (ACAP)	Model 3B (KImpact)	Model 3C (KBreadth)	Model 3D (All)
Intercept	12.221***	2.776+	-0.915	0.629	5.342**	0.031
	(1.177)	(1.546)	(1.971)	(1.683)	(1.758)	(2.246)
Firm size		0.456**	0.644***	0.548**	0.727***	0.915***
		(0.174)	(0.184)	(0.174)	(0.195)	(0.201)
Previous performance		0.520***	0.563***	0.511***	0.504***	0.537***
		(0.028)	(0.031)	(0.028)	(0.028)	(0.031)
Change of control firms' performance		0.111**	0.114**	0.110**	0.115**	0.116**
		(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
Multiple introductions		1.526+	1.339+	1.272	1.909*	1.493+
		(0.807)	(0.803)	(0.798)	(0.814)	(0.807)
Industry Concentration		-5.063	0.138	-1.332	-4.134	3.193
		(15.095)	(15.124)	(15.074)	(15.020)	(15.054)
Industry R&D intensity		-1.946	-2.177	0.059	-2.099	-0.808
		(5.697)	(5.660)	(5.674)	(5.670)	(5.637)
Absorptive capacity			0.171**			0.154**
			(0.057)			(0.057)
Knowledge Impact				0.996**		0.725*
				(0.317)		(0.324)
Knowledge breadth					-6.642**	-5.508*
					(2.197)	(2.200)
Random Effects:						
Between industries	6.03	0.00	0.00	0.00	0.00	0.00
Between firms	80.80	27.10	26.54	25.98	26.86	25.50
Residual	17.36	16.52	16.38	16.48	16.31	16.22
Model fit:						
AIC	5217.15	4959.93	4952.87	4952.12	4952.74	4942.69
-2 Log-likelihood (Deviance)	5209.15	4939.93	4930.87	4930.12	4930.74	4916.69
Anova significance		0.000	0.003	0.002	0.002	0.000

*Note: ***: p-value <0.001; **: p-value <0.01; *: p-value <0.05; +: p-value<0.1*

Table 8 HLM Estimation for Tobin's q

	Model 1	Model 2	Model 3A (ACAP)	Model 3B (KImpact)	Model 3C (KBreadth)	Model 3D (All)
Intercept	1.680***	1.963***	1.337***	1.572***	2.418***	1.635***
	(0.076)	(0.328)	(0.400)	(0.348)	(0.348)	(0.422)
Firm size		-0.036	-0.001	-0.028	0.010	0.037
		(0.027)	(0.029)	(0.026)	(0.029)	(0.031)
Previous performance		0.481***	0.475***	0.477***	0.459***	0.454***
		(0.038)	(0.038)	(0.038)	(0.038)	(0.038)
Change of control firms' performance		0.414***	0.411***	0.433***	0.400***	0.413***
		(0.048)	(0.047)	(0.048)	(0.047)	(0.047)
Multiple introductions		0.046	-0.002	-0.001	0.141	0.063
		(0.121)	(0.121)	(0.120)	(0.122)	(0.121)
Industry Concentration		-13.691**	-11.272*	-12.212**	-13.399**	-10.579*
		(4.348)	(4.401)	(4.312)	(4.284)	(4.318)
Industry R&D intensity		-2.462*	-2.105*	-1.903+	-2.512*	-1.852+
		(1.019)	(1.019)	(1.022)	(1.005)	(1.011)
Absorptive capacity			0.029**			0.022*
			(0.011)			(0.011)
Knowledge Impact				0.202**		0.137*
				(0.067)		(0.069)
Knowledge breadth					-1.180***	-1.061**
					(0.333)	(0.329)
Random effects:						
Between industries	0.000	0.000	0.000	0.000	0.000	0.000
Between firms	1.010	0.530	0.510	0.500	0.500	0.470
Residual	0.500	0.480	0.470	0.480	0.470	0.470
Model fit:						
AIC	2107.880	1967.810	1962.600	1960.839	1957.320	1950.522
-2 Log-likelihood (Deviance)	2099.880	1947.810	1940.600	1938.840	1935.310	1924.520
Anova significance		0.000	0.007	0.003	0.000	0.000

*Note: ***: p-value <0.001; **: p-value <0.01; *: p-value <0.05; +: p-value<0.1*

Specifically, H2 predicts that absorptive capacity positively moderates the relationship between TNP introduction and firm performance. From estimations of ROA and Tobin's q, we find that this hypothesis is supported. In Table 7, the individual model, Model 3A, and the full model, Model 3D, show that absorptive capacity was a significant predictor of ROA upon TNP introduction. The un-standardized coefficients of absorptive capacity was 0.171 (s.e. = 0.057) in Model 3A, and 0.154 (s.e. =0.057) in Model 3D. For testing the impact on Tobin's q, absorptive capacity is also a significant and positive moderator. Coefficients for absorptive capacity in Models 3A and 3D were 0.029 (s.e. = 0.011) and 0.022 (s.e. =0.011), respectively (Table 8).

We argue that knowledge impact has positive effect on firm performance. This is supported by our empirical data. As shown in Table 7, we find the coefficient of knowledge impact is 0.996 (s.e. = 0.317) in Model 3B and 0.725 (s.e. =0.324) in Model 3D; both were highly significant ($p < 0.05$). However, our results show that knowledge breadth negatively moderates the relationship between TNP introduction and ROA, and coefficients of individual model (Model 3C) and full model (Model 3D) were -6.642 (s.e.=2.197) and -5.508 (s.e.=2.200), respectively. Consistent results were obtained for tests of moderating impact of knowledge breadth on firms' Tobin's q (Table 8).

Chapter 6 Discussion

Our results indicate that when a firm engages in product innovation, its long-term performance is enhanced. Compared to control firms from the same industry, sample firms with TNPs obtained significantly high financial performance a few years after TNP introduction. The development of TNP enables a firm to gain higher competencies and obtain higher accounting-based and market-based performance. This result is consistent with prior research, which suggests the development of TNPs helps distinguish innovative firms from mundane firms, leading to competitive advantages. Since TNPs have "destructive power" over existing competencies in an industry, the first movers enjoy high competitive advantages and create new markets. The average increase in ROA was 0.77% in the year of introduction, which further increased to 1.59% in the second year and reached 2.18% in the third year. The abnormal return of TNP introduction dropped in the fourth year to 0.98%, although statistically it was still significantly higher than non-innovative firms. Consistent results were obtained for the impact on TNP introduction to Tobin's q of a firm as evaluation by the stock market.

We also find that in the setting of TNP development, the capability of appropriating firm performance is contingent upon some important technological characteristics of the firm. Our findings suggest that absorptive capacity does increase firm performance to a great extent as the TNP is introduced in the market. Controlling for other factors, there is 0.154% of change in ROA and 0.022 unit of change in Tobin's q when absorptive capacity changes one unit. This positive relationship indicates that a firm with high absorptive capacity can create more competitive products and, therefore, enjoy higher returns from markets in the long term. George, Zahra, Wheatley and Khan (2001) suggested that absorptive capacity not only enhances the technological competence of a firm but also enables it to know markets and rivals better. This type of firms are in a better position to effectively and efficiently exploit knowledge gained from both inside and outside the firm and transform it into new products.

The importance of knowledge impact has not been examined in prior OM literature. The creation of impactful knowledge puts the innovator in an advantageous position in the industry, and enables the firm to maintain its leadership position in certain technological areas. However, the spillover effects may also dominate when knowledge becomes impactful (De Carolis, 2003). McGahan and Silverman (2006) pointed out that a significant innovation of a focal firm can give rise to technological opportunities for competitors in the industry and the focal firm may thus lose its leadership position in certain technological areas in the future. On the contrary, our results support that knowledge impact increases the value of TNPs. In this study, knowledge impact was measured by patent citations, which were proved to have a significant positive impact on focal firms' performance. McGahan and Silverman (2006) also found that the financial value of an incumbent firm depends on innovation by competitors, and its market value is negatively related to “important” innovation by outside inventors. Similar to their results, we find that the more impactful a firm's knowledge is, as compared to others, the higher is its financial performance when the new product is introduced. Our results show that when we rule out the effect of other predictors in our model, one unit increase in knowledge impact (a patent receives one more citation on average) leads to 0.725% increase in ROA and 0.137 increase in Tobin’s q on average. From the patent protecting perspective, we can also see that patents help innovative firms enhance their abilities to earn returns from their knowledge and avoid losing their advantages because of imitation by others.

Our research provides evidence that knowledge breadth does not help firms increase TNPs' competence. We find that knowledge breadth has a significantly negative moderating effect on firm performance upon TNP introduction. In our study, knowledge breadth is measured on the interval of [0, 1], and the results indicate that 0.1 increase in knowledge breadth leads the firms to have 0.5508% decrease in ROA and 0.1061 decrease in Tobin’s q, when we control other variables. Although we argue that firms with broad knowledge should benefit from a combination of various kinds of knowledge, this is not supported by our empirical data. One possible explanation is that the benefits of wider knowledge stock are offset by its disadvantages. In developing TNPs, focused learning of specialized areas appears to be more important (Henard & Szymanski, 2001). It is also possible that firms with high knowledge breadth might actually encounter higher costs in managing diversified knowledge stocks and maintaining accessibility of multiple knowledge resources (Jiang, Tao, & Santoro, 2010; Parkhe, 1993; Richard, Murthi, & Ismail, 2007).

Besides, TNP introduction has cannibalization effect on the current technology market and the willingness to cannibalize determines the success of TNP. It is long believed that organizational innovation is a kind of "creative destruction" (Schumpeter, 1942). Chandy and Tellis (1998) in their survey find that willingness to cannibalize has a strong positive effect on radical product innovation. Firms with very wide knowledge breadth might be relatively reluctant to make change to its existing technology market, because the fresh investment in TNP would potentially render the current investments in current technology obsolete (Chandy and Tellis, 1998). The decreased willingness to completely switch to TNP might exist in those firms with a lot of current products and technology. In other words, the wider a firm's knowledge base, the harder for it to make quick decision to allocate enough resources on the new technology and give up prior products. The unwillingness might lead the innovating firm fail to appropriate all the benefits of TNP, and their competitors might do better than them.

According to the KBV of the firm, core knowledge capacities are much more valuable. Such knowledge is specific to certain application areas and settings, enabling the firm to develop unique TNPs. Some researchers suggest that greater breadth of knowledge and technology causes the firm to spread resources too thinly (Wernerfelt & Montgomery, 1988). When a firm puts too much energy and human resources in diversified areas, it dilutes its core competence and loses out to competitors who concentrate on a narrow and specific knowledge area. KBV also suggests that firm has an important role in coordinating the knowledge created by many specialists (Grant, 1996). Facing a technology environment with diversified and complex knowledge, firms need an efficient mechanism to transfer, integrate and embed the knowledge into final products. However, to aggregate knowledge of different members of the organization is a common problem for firms (Grant, 1996). So, it is possible that broad knowledge stock undermines firm's long term competence in product innovation.

Chapter 7 Conclusion

After discussing the results of this study, this chapter presents the summary of the main findings on TNPs' implications for firm value, and the role of knowledge characteristics in the link between TNPs and firm value. In this chapter, we also offer implications for academics and practitioners. Then, limitations of this study are discussed and directions for future research are presented.

7.1 Summary of Main Findings

Whether TNP introduction leads to superior returns and the factors moderating such returns have long been examined by management researchers. In this research, we first examine the abnormal returns of innovative products and then investigate how some important knowledge characteristics of a firm increase or decrease the value of TNPs. Consistent with prior literature, we find that technological innovations enable firms to create significant economic value. The rare and valuable knowledge attained during new product development helps firms strengthen their competence. As technology leaders, innovative firms enjoy higher returns as they create new markets. We find that firms with TNPs increase both their accounting-based and market-based performance measures, although developing TNPs is highly uncertain and costly (Calantone et al., 2010; Sorescu et al., 2003).

To the best of our knowledge, this research is the first to consider knowledge characteristics having moderating effects on TNP performance. Our findings indicate that firm's own knowledge characteristics can greatly affect firm's TNP performance. High absorptive capacity and knowledge impact can strengthen the products' competitive advantage. To ensure that a new product succeeds in the market, firms need to make substantial efforts to increase absorptive capacity and knowledge impact. Prior research has pointed out that identifying, assimilating and combining outside knowledge into a firm's own knowledge forms an important source of competitive advantage (Zahra & George, 2002). This is because a firm can comprehend technology change in the market and competitors' knowledge development quickly, and instantly respond to market needs.

To develop TNPs, firms face a trade-off between depth and breadth of their knowledge stock (Leiponen & Helfat, 2010). To develop a dominant position and effective management, a firm needs to focus on limited number of strategic areas.

7.2 Implications for Academics and Practice

7.2.1 Implications of Research

This study contributes to the theory of product development. It adds to the existing literature on TNP development and TNP implications in terms of firm value. The results support that we can apply KBV of firm in new product development setting, and that the new knowledge created during TNP development can differentiate innovating firms' performance from non-innovating firms.

The objective measure of firm value and identification method of TNPs in this study also contribute to empirical studies of innovation and new product development. These alternative methods (besides interviews and surveys) further validate the notion that TNP development is valuable for a firm's competitive advantage. In addition, the framework in this study captures the moderating effect of firm's knowledge characteristics on the relationship between TNP introduction and firm value. The results suggest that knowledge characteristics play different and significant roles in affecting TNPs' impact on firm value.

7.2.2 Implications for Practitioners

The framework has several implications for firm managements. Because new product development plays a central role in achieving a sustainable competitive advantage and value creation, managers are expected to design strategies to leverage firm capabilities and resources for balancing development of non-innovative products and TNPs.

One key finding of this study is that the positive abnormal returns associated with TNP introduction support the notion that TNP development is vital for a firm that wants to augment its value. The superior performance of firms developing TNPs underscores the ability to generate higher operating income and shareholder value. Therefore, on the basis of evidence from extant research, it may not be advisable to reduce investment in technological innovation and in new product development. This result should also be of importance in the context of knowledge management. While first movers face some disadvantages in embedding radically new technology in their products, the positive returns imply that in developing TNP is beneficial for long term competence.

This study provides managements with a framework to consider advantages and disadvantages of firm's knowledge characteristics that affect TNP's impact on firm performance. With regard to the moderating factors, our study provides evidence that knowledge characteristics of firms play a significant role. Results indicate that higher absorptive capacity and knowledge impact can have positive moderating effect. Therefore, during the TNP development process, it is advisable to invest in R&D in similar fields, and learn quickly new knowledge from suppliers, competitors and customers. By assigning greater importance to knowledge base, firms can strengthen their position in TNP development and commercialization. But this doesn't mean firms need to broaden the scope in technological advancement. Rather, it is more meaningful to concentrate on a narrow field of technology. Thus, managers should be careful when they make decisions about new product innovation and should consider knowledge characteristics of the firm. Given the important effect of firms' knowledge characteristics, a firm should identify an optimum solution based on its knowledge base, and establish a balanced strategy to develop and introduce TNPs.

The patent-based metrics of knowledge characteristics can be computed in accordance with publicly available data (i.e., database from patent office or other sources) over time, and it can provide a framework of reference that managers can use for tracking, monitoring and adjusting their strategy for knowledge creation and application.

7.3 Limitations of This Study

Our study is not without limitations. One limitation is that we retrieved our data from the COMPUSTAT database and selected publicly listed firms from the U.S. in the sample. As a result, we cannot generalize the results to non-listed (normally smaller) firms and to other countries, such as China. Meanwhile, this study was designed to provide a snapshot of results across different segments in the manufacturing industry, and didn't compare and discuss results from different industries. Therefore, these results cannot be applied to a specific business segment, without considering the related context.

Another problem lies in measurement of knowledge characteristics in a firm. Due to limitations of secondary data, we can only use R&D intensity to measure absorptive capacity, and patent data to measure knowledge impact and knowledge breadth. Although these measurements are important and are often used in research, they can't reflect all aspects of knowledge characteristics of a firm. Furthermore, there is no consensus on truncation of time period, though we tried our best to find the valid time period to determine a firm's absorptive capacity, knowledge impact and knowledge breadth. Besides, the utility of the patent-based measures of knowledge characteristics is likely to be limited to industries in which patents are themselves meaningful indicators of knowledge of the firm. Therefore, it is more advisable to take into consideration the measurement issue when comparing the constructs with other studies.

Finally, this study is still exploratory and we didn't examine TNPs' impact on firm value either in the short term after introduction of TNPs or during the whole life cycle of the products. We investigated TNPs' impact for four years following introduction. Besides, due to the limitation of long term measurement of firm performance, our study can include some firms in the sample that might not survive in later years and exit the market. This kind of failure might make our results overestimated.

7.4 Future Research

The above limitation of this study suggests important areas of further research. First of all, replicating this study in other industry contexts (e.g., service industry) and other countries with similar methods and data sources, can enable a more complete assessment of TNPs' implications for firm value. Importantly, through this way, generalization of the findings of this study can be examined. It would also be interesting and valuable to include other types of knowledge characteristics, including knowledge about marketing and customers, and other intangible knowledge in firm management (e.g., knowledge depth and knowledge specificity). For instance, one possible direction could be whether customers' high perception of novelty and benefits associated with TNPs lead to higher firm performance. This may help reinforce the understanding of factors from market on TNPs' success.

Another opportunity for further research is to examine TNPs' impact and moderating factors at the project or sub-firm level. The reason is that projects usually are the repository of equipment, skills, resources and personnel that are organized together from diverse functional areas during development of TNPs (Tatikonda & Rosenthal, 2000). Market failure can occur not only because of low level of operational efficiency but also poor planning of productivity and deficient market proficiency. Therefore, the analysis on lower levels can examine directly whether TNPs' value creation capabilities are a result of project operation.

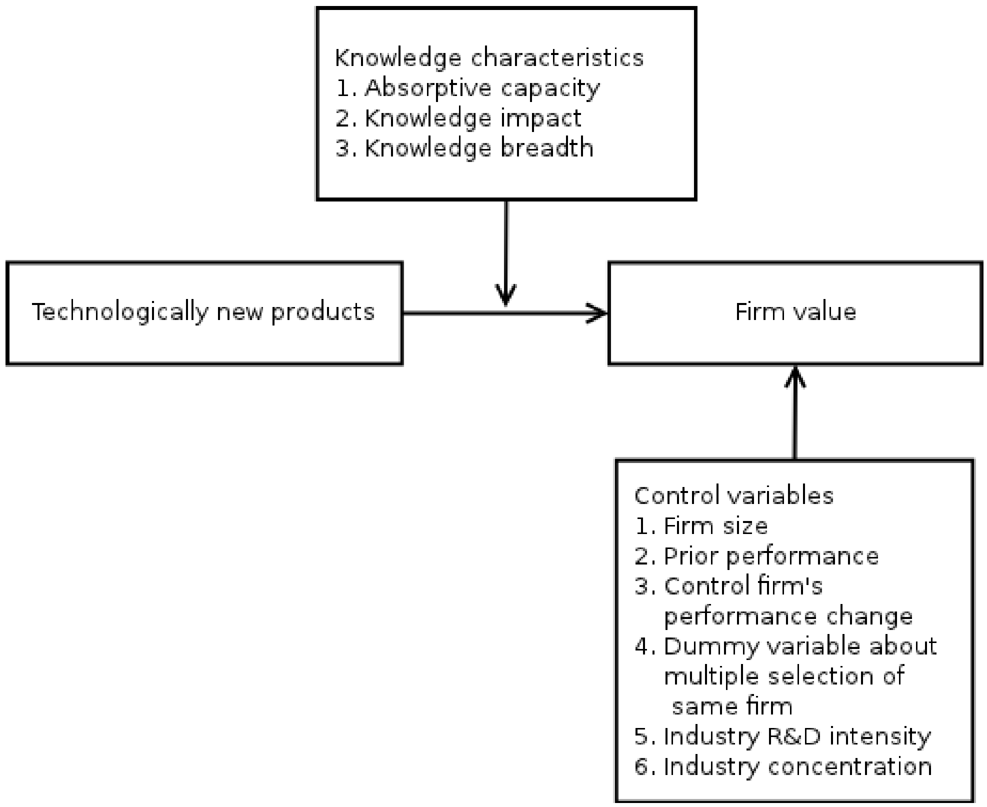
More study on the moderating effect of the risk and cost in TNP development is beneficial. In applying high technology in new product development, the innovating firms have to face the associated high costs and risks. While prior research has already provided some insights about high R&D investment and its direct impact on TNP development. Specifically, scholars tend to uncover whether high cost increases the chance to bring out new products. But few studies begin to investigate costs and risks as moderating factors in appropriability of TNPs. It is possible that high costs or risks could limit rivals' intention and efforts to imitate the TNPs, which gives the innovating firms more opportunities to achieve higher profit.

In our study, we examine the impact of knowledge characteristics in a radically new technology setting. Future research can extend this study to an incrementally innovative product setting, and compare the results from different settings. For example, in both settings of developing incrementally new products and TNPs, does knowledge breadth of firms have similar or contradicting moderating effects? This comparison would allow us to understand the specific impact of knowledge characteristics on both radically different and incrementally innovative product settings. The combination of the two would help us examine the relevance and limitations of KBV in depth. We can obtain further insights about KBV and build more specific theories in OM areas.

Another possible avenue for future research is to expand the methods used in this study to examine effects of TNP introductions on competing firms' value.

The growing literature on radical product innovation is largely silent on the issue of competitor response and their value (Aboulnasr et al., 2008). In other words, we have little empirical evidence regarding the relationship between a firm's value and TNPs by its rivals (McGahan & Silverman, 2006). This ambiguous relationship needs additional reliable and in-depth investigation. Considering the destructive impact on the industry, firms should have some responses. On one hand, to respond to radical innovation and product introductions, competitors should make an effort to hedge the negative impact from the innovating firms. On the other hand, with "market stealing" effects and knowledge spillover effects, competitors can mitigate the harmful effect of innovation activities by rivals, and even take better advantage of the technological opportunity. In such cases, answering the question about how knowledge characteristics moderate the relationship between firm performance and TNPs by rivals, becomes essential for theoretical development of knowledge management. It may be interesting to compare these results, and shed light on many of the debates on TNPs' implications for innovating firms and competitors.

Appendix A Conceptual Framework of the Theoretical Model



Appendix B Examples about Sample Selection

Award Example: The R&D 100 Awards

Award Organization: R&D Magazine

About the award:

> **"**The R&D 100 Awards**,** widely recognized as the "Oscars of Innovation", identifies and celebrates the top high technology products of the year".
>
> …
>
> "Many of these have become household names, helping shape everyday life for many Americans. These include the flashcube (1965), the automated teller machine (1973), the halogen lamp (1974), the fax machine (1975), the liquid crystal display (1980), the Kodak Photo CD (1991), the Nicoderm anti-smoking patch (1992), Taxol anticancer drug (1993), lab on a chip (1996), and HDTV (1998)". (Retrieved from www.rdmag.com, 2011-06-20)

Example one:

Step 1 (Identify TNPs and innovating firms based on the award list):	
Award name:	R&D 100 awards
Award date:	2002
The awarded TNP:	MKS PICO Leak Detector (sniffer version)
The awarded firm:	MKS Instruments Inc.
Step 2 (Check whether the innovating firm is public-listed in US based on COMPUSTAT):	
Gvkey (from COMPUSTAT):	119275
Step 3 (Verify the announcement date of the TNP into market based on Lexis-Nexis (Academic)):	
Announcement date:	2001/12/03
Announcement source:	PR Newswire
Announcement content:	MKS Instruments, Inc., (Nasdaq: MKSI), a global leader in the manufacture of components and subsystems for vacuum- and gas-based processes, has announced that it is ramping up for volume production of the world's smallest portable mass spectrometer-based leak detector, the MKS PICO(TM) Series. A beta test version of the PICO was shipped to selected customers earlier this year, and since then, the PICO has rapidly gained acceptance across a range of industries as the world's first truly portable mass spectrometer-based leak detector. Weighing in at a mere 16 lbs., MKS' PICO is easily transported in a variety of industrial work settings, eliminating the need for push carts used to transport leak detectors that commonly weigh as much as 70 lbs. ...
ProID: 7291; Sample ID: 424; Announcement ID: 632	

Example two:

Step 1 (Identify TNPs and innovating firms based on the award list):

Award name:	R&D 100 awards
Award date:	2006
The awarded TNP:	VDIM - Vehicle Dynamics Integrated Management - with Active Steering
The awarded firm:	Toyota Motor Corporation

Step 2 (Check whether the innovating firm is public-listed in US based on COMPUSTAT):

Gvkey (from COMPUSTAT):	19661

Step 3 (Verify the announcement date of the TNP into market based on Lexis-Nexis (Academic)):

Announcement date:	2004/06/03
Announcement source:	Kyodo News International, Tokyo
Announcement content:	Toyota Motor Corp. said Thursday its new models scheduled to hit the market shortly will incorporate new safety measures to prevent accidents and help reduce injuries during collisions. The new technologies include a system called vehicle dynamics integrated management, which begins integrated control of the brakes, engine and steering at an earlier stage...

ProID:8758 ; Sample ID: 460; Announcement ID: 863

Example three:

Step 1 (Identify TNPs and innovating firms based on the award list):

Award name:	R&D 100 awards
Award date:	1999
The awarded TNP:	ELITE Enhanced Polyethylene Resins
The awarded firm:	DOW CHEMICAL

Step 2 (Check whether the innovating firm is public-listed in US based on COMPUSTAT):

Gvkey (from COMPUSTAT):	4060

Step 3 (Verify the announcement date of the TNP into market based on Lexis-Nexis (Academic)):

Announcement date:	1997/03/05
Announcement source:	Chemical Week
Announcement content:	DOW CHEMICAL HAS ANNOUNCED THE commercialization of linear low-density polyethylene (LLDPE) resins made using its Insite single-site catalyst technology... ...The new Dow products, which will be trade named Elite, will be sold as high-performance LLDPE. Dow will initially market the resins between its Dowlex LLDPE and the company's line of specialty polyolefins.

ProID: 7268; Sample ID: 384; Announcement ID: 228

Appendix C Classification of Patent Classes into Technological Categories and Sub-categories

Category	Category name	Sub-category	Sub-category name
1	Chemical	11	Agriculture, Food, Textiles
		12	Coating
		13	Gas
		14	Gas
		15	Resins
		19	Miscellaneous-chmeical
2	Computers and Communications	21	Communications
		22	Computer Hardware and Software
		23	Computer Peripherals
		24	Information Storage
		25	Electronic business methods and software
3	Drugs and Medical	31	Drugs
		32	Surgery and Medical Instruments
		33	Genetics
		39	Miscellaneous-Drugs and Medical
4	Electrical and Electronic	41	Electrical Devices
		42	Electrical Lighting
		43	Measuring and Testing
		44	Nuclear and X-rays

Category	Category name	Sub-category	Sub-category name
		45	Power Systems
		46	Semiconductor Devices
		49	Miscellaneous-Electrical and Electronic
5	Mechanical	51	Materials Processing and Handling
		52	Metal Working
		53	Motors, Engines and Parts
		54	Optics
		55	Transportation
		59	Miscellaneous-Mechanical
6	Others	61	Agriculture, Husbandry, Food
		62	Amusement Devices
		63	Apparel and Textile
		64	Earth Working and Wells
		65	Furniture, House Fixtures
		66	Heating
		67	Pipes and Joints
		68	Receptacles
		69	Miscellaneous-Others

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